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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

AUGUST 1922

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

What is the Function of an Engineering Department?

IS IT to give the Sales Department something to sell? That may be its function today, but if you will look ahead into tomorrow you will discover that the Engineering Department must do more. The Engineering Department will have to give the Sales Department something which is *easy* to sell. Car buyers are going to dig deep to find and get their money's worth.

Why do Men Buy Motor Cars?

Isn't it because they want something to ride in? And isn't that the *only* reason? And isn't it natural that these men, while they are riding, will prefer to ride comfortably?

Practically all cars of today possess ample motor ability. But how many of these cars possess a corresponding degree of roadability? The minute a man runs off a good road and on to a poorer road, off comes his foot. His motor ability is of no use to him. He can't use it. The mere boulevard car will shortly be a thing forgotten.

The Car with Roadability is Already Here

Men want, and they will dig until they get, a car that *does* possess roadability.

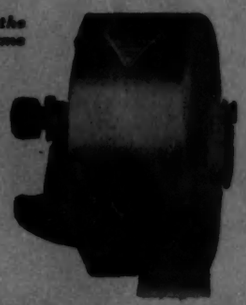
The General Manager who gets his Sales Department and his Engineering Department together *now* on this matter of roadability will have little to worry about a few months hence when real competition sets in. They will have a jump which will be invaluable because they will be offering exactly what each and every future car purchaser is going to look for and insist upon getting. Men are learning fast that the old standards of so-called motoring comfort are no longer necessary and need not be tolerated.

True Roadability Can be Built Into Any Car

This can be done by means of supple springs to absorb road shocks and store shock energy and by means of Stabilators to dissipate this energy before the springs can unload it against the car body and passengers.

The time to get busy on this matter is now—not after your competitors have done it.

Look for the Silver Name Plate



Exactly opposite to snubbing

In checking spring recoil, Stabilators work exactly opposite to the snubbing principle. Instead of checking with a jerk at the tail end of the recoil movement, Stabilators get on the job at the very beginning of the movement and smoothly ease you back to normal. Results produced by the one method give no conception of those produced by the other. They are different to the point of absolute oppositeness.

JOHN WARREN WATSON COMPANY
Twenty-Fourth and Locust Streets
Philadelphia, Pa.

WATSON STABILATORS

CHANGE THE WHOLE NATURE OF YOUR CAR

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XI August, 1922 No. 2

Chronicle and Comment

Operations Engineering

WE should maintain the broad view that the operating phase of the automotive business is just as important as the building of motor vehicles, in connection with bus lines or other motor-vehicle transport.—Past-President Manly.

Motor Car Engineering Vice-Presidency

BY way of addition to its report printed in the July issue of THE JOURNAL, the Nominating Committee of the Society has advised that it has nominated A. F. Masury to serve as second vice-president representing motor-car engineering during 1923.

Membership Increase

WE want to increase the membership of the Society, but we must be particular as to the kind of men we try to interest. There is not anything to be gained by getting a man in this year who will drop out next year.—Lon R. Smith, Chairman of Membership Committee.

The Sections

THE Sections Committee will render every assistance possible to the Sections officers during the summer when the latter will be planning meetings and selecting authors of papers of greatest general interest in the respective Section territories. The Committee is anxious to receive suggestions and constructive criticisms from members with a view to making the Sections meetings as interesting and valuable as may be.—A. K. Brumbaugh, Chairman of Sections Committee.

Standardization Surely Pays

ACCORDING to the statistics furnished by manufacturers and other authorities in the automotive industry, the annual savings resulting from the standardization effected by the Society of Automotive Engineers amount to 15 per cent of the annual turnover in the industry. This turnover is about $5,000,000,000, and the estimated saving therefrom amounts to $750,000,000 a year. No other society or association that we know of has made such great progress in the practical application of standardization. Hundreds of items have been made the subject of investigation and study, and many of the component parts used in automobile construction are now made by all manufacturers according to definite specifications. The marked improvements made in automobiles, without a proportionate increase in price, have been due in large measure to this work.—*Machinery.*

A Meeting on Production Problems

A NATIONAL meeting of the Society will be held in Detroit, Oct. 26 and 27, to discuss problems of automotive production. The meeting is to be known as the Automotive Production Meeting. Papers treating current production problems in a simple and practical way will be read and fully discussed in morning meetings on each of the two days. The afternoons will be devoted to factory inspection-trips especially arranged for the purpose of viewing new and advanced production methods that will particularly interest the tool, inspection and production men. The principal object of this meeting is the promotion of an interchange of experiences between practical factory men on automotive production problems that are troubling them in their daily work. Formality will be ruled out of the sessions, which are to be as near the round-table type of impersonal discussion as possible; they are to be forums of practical experience and not theoretical controversies. A Production Dinner will be held Thursday evening, Oct. 26, where social friendships between production men will be promoted in an atmosphere of informality and good fellowship. Announcement of further details of the Production Meeting will appear in the September issue of THE JOURNAL and a special issue of the *Meetings Bulletin.*

Grading of Members

IT has been the policy of the Society for many years, in the interpretation of Constitutional provision, that, aside from minimum age and distinguished service or noteworthy accomplishment, evidence of ability in some important phase of automotive engineering is requisite to qualify for Member grade. The committees and Councils of the Society have followed this interpretative policy faithfully and consistently in intent and in action; although, as stated by President Bachman at White Sulphur Springs, neither a committee nor a Council can be infallible.

In connection with the proverb, "Give a dog a bad name and hang him," it has been said that rules can be

made acceptable and ideals realized only as they appeal to something in human nature and awaken in it an active response. Rules have to be interpreted and responsibility for the interpretation taken by those making it. If the members of the Council knew personally those applying for membership or grade transfer, it would still be difficult to reach decisions in many cases. Dealing almost exclusively with written evidence, the problem is indeed difficult.

There was a healthful discussion of important phases of this whole matter at the business session of the Summer Meeting, statements being advanced to the effect that it is unduly difficult to secure Member grade and also in support of the general idea that it has been and is granted too freely.

The Society is an engineering organization. Only those of Member grade have voting or office-holding power in it as a national organization. It is recognized that many who cannot be classified as engineers can be very helpful in and assisted by the avowed and generally accepted activities of the Society. This has been fundamental in our procedure for over a decade, and those of the types indicated have been and are welcomed into the ranks.

In maintaining the integrity of the Society as an engineering organization, the members as a whole can aid greatly by familiarizing themselves adequately with the methods followed and advising individually in close cases in grading. They should, of course, return promptly, after filling them out very conscientiously in view of the rules, the reference blanks furnished them from time to time; and, in addition, they should write special letters as occasion requires. Each application for membership or transfer is considered carefully by several persons before it is acted upon by the Council. The more specific information available in each case, the better.

Applicants should give in suitable written form a comprehensive specific record of their education and professional or business experience. Frequently men who might well be considered for Member grade if sufficient information with regard to their work were at hand, fail to furnish the data needed. Naturally, in case of doubt the Member grade will not be recommended or granted by the Council. An applicant should have a clear idea of just what status he seeks in the Society and furnish full information so that an intelligent decision can be made in the first instance on this basis. Otherwise, in the event of dissatisfaction on his part, a needless amount of his time, as well as that of others, will be taken in further steps.

Of course, a technical-school education or an enginneering degree is not requisite to Member-grade qualification. They have weight and may be decisive in a case that is otherwise close. Neither is the immediate occupation conclusive. A person who is qualified by technical training or experience to design or construct complete automotive apparatus or their important component parts may not be engaged in such work, but that would not bar him from election to Member grade. An applicant may be competent to exercise responsible technical supervision of the production of materials germane to the construction of automotive apparatus; to take responsible charge of automotive engineering work; or to impart technical instruction in the design and construction of automotive apparatus. Having any of these qualifications in the degree contemplated by the constitutional provisions, he may be elected a Member regardless of the work he is doing at the time. However, if there were any doubt as to his engineering qualification, he might be graded as an Associate or a Junior, or not elected to any grade of membership.

Frequently applications are received from men who are not qualified for any grade of membership in the Society. They are generally advised to subscribe for THE JOURNAL, placing them on a basis somewhat similar to that of the Enrolled Student. These men are for the most part mechanics or repairmen who are endeavoring to follow automotive engineering matters in a somewhat serious way.

It is the custom to publish the names of applicants in THE JOURNAL prior to considering electing them; and precaution is taken not to elect persons who are not of reputable character.

One of the difficult phases of the interpretation of the constitutional provisions as to Member qualification, C8 of the Constitution, arises in connection with the clause "qualified to act as designers or constructors of complete automotive apparatus *or their important component parts.*" The italicized words obviously raise a real question as to the line of division. What is an *important* component part of automotive apparatus? Incidentally, how many or who are qualified to design or construct a *complete* automotive apparatus, involving the application of knowledge of probably more sciences and arts than any product of manufacture other than shipbuilding? Rational methods of procedure must be followed in various respects in interpreting any constitutional provision.

It was argued forcefully at one time that a magneto designer was not entitled to Member grade. This has not been the prevalent view for some time. Latterly there has been discussion as to the grade of membership to which specialists in the design of such articles as helical springs and pipe fittings are entitled, some insisting that the most experienced and successful men in these lines should not be elected Members. This is not the view of the Council.

In general, those who are engaged in the automotive and related industries in a responsible commercial, financial or manufacturing capacity, or so occupied as to be able to *cooperate* with automotive engineers, are qualified to be Associates of the Society. The Associateship is not an inferior grade as such, but merely a ranking in accord with the basic fabric of the Society. There is nothing inconsistent in the fact that an Associate of the Society may in his own business employ a Member of the Society. The Society is an *engineering* organization, in which cognizance is taken of the many ramifications of the work of the automotive engineer, and a commonsense method of procedure provided for and followed. If a man is competent to and so situated as to be able to cooperate helpfully in the broad work of the Members, he is qualified to be an Associate of the Society.

Somebody said, "No generalization is true, including this one." Many cases have to be considered specially. What has been said or done before does not always fit. The best basis for judging an individual or an organization is *performance*, giving due weight to what is important.

Members who do not understand or are dissatisfied with membership gradings should send to the Council specific statements of their view. The Council is without question liberal in the interpretation of what an engineer is, based on what he has done, with reference to automotive engineering. The fact that a man is very well qualified in some unrelated field of engineering does not, of course, entitle him to membership in the Society.

Temperatures of Pneumatic Truck-Tires

By F. O. Ellenwood[1]

Buffalo Section Paper *Illustrated with* Charts and Photographs

After pointing out that the operating temperature is a vital factor in the life of a pneumatic truck-tire, the author outlines an investigation that was conducted at the plant of the Goodyear Tire & Rubber Co. This sought to determine (*a*) the best means of measing tire temperatures; (*b*) the temperature effect of inflation-pressure, load, long runs, frequency of stops, and the sizes of the rim and the tire; (*c*) the temperature of various designs of tire; and (*d*) some suitable means of reducing large-tire temperatures. The main reason for the rise in the temperature of a tire is stated to be the generation of heat resulting from rapid flexing; and the various factors having to do with this generation of heat and its dissipation to the atmosphere are listed.

The laboratory testing-machine and the methods and apparatus employed to measure the temperatures are described. One method was to measure the initial temperature and determine the rise by the increased pressure as shown by a gage fastened to the hub. The necessary corrections for air leakage and changes in the volume of the tire during operation were determined; the results are presented graphically. A type of tire thermometer was subsequently designed and used, but this was not satisfactory on account of the great differences between the thermometer readings and the temperatures as calculated by the pressure-volume method.

Thermocouples placed inside the tubes were also tried and results that checked fairly well with those calculated by the pressure-volume method were obtained. Also a detachable type of thermocouple was placed in a hole drilled through the tread to the cushion or carcass as desired.

The necessity of knowing that the air in the tubes was not saturated required the use of an air separator for inflating the tires. The effects of convection currents inside the tube on the thermocouples and thermometers are discussed. The theory as to the manner in which the temperature of a tire is reduced by using a small quantity of water inside the tube is given and convincing experimental evidence is presented to substantiate this theory.

After summarizing his conclusions, the author expresses the belief that the study of pneumatic-tire temperatures is of much greater commercial importance and possibly of greater scientific interest than is generally realized. The rise in the temperature of a tire is a direct and sensitive indication of the waste of energy due to its operation. While this loss cannot be eliminated, it can be reduced by proper selection and combination of materials.

THE development of pneumatic tires has been very great and rapid, so that now we secure wonderful service if they are given half a chance in the way of proper care. It is only natural that owners of trucks should desire pneumatic tires on their vehicles used in service where speed is of considerable importance. These large tires carrying heavy loads have brought many new and perplexing difficulties to their manufacturers. One such problem is that of making a large tire that will carry heavy loads for long distances at continuously high speed in hot climates and yet have a long life, for the casing and the tube. Under such conditions there has been some trouble from premature failure and yet the same casings and tubes would be very satisfactory in cool climates, thus showing clearly that the operating temperature is a vital factor in the life of a tire. The investigation described herein was therefore undertaken for the purpose of trying to do the following things:

(1) Find out the best means of measuring tire temperatures
(2) Determine the temperature effect of inflation-pressure, load, long runs, frequency of stops, undersized rims and tire size
(3) Determine the temperature of various designs of tire
(4) Find some suitable means of reducing large-tire temperatures

The experiments have all been made during the past 2 years at the Akron plant of the Goodyear Tire & Rubber Co. and I desire to express my appreciation of the commendable policy that permits a large part of the information thus far obtained to be given to the public.

What makes a tire become hot? This question has been asked many times by laymen and often by engineers. Various answers have been given. Many laymen think it is due to the slippage between the tread and the road. This is a factor of only the very slightest importance in nearly all cases. The main reason for the rise in temperature of a tire is the generation of heat by the rapid flexing of it or, in other words, its hysteresis.

A tire is made up of many layers of cotton cord and rubber compound, each of which has been most carefully prepared and fitted together in a very definite and painstaking manner; then the whole mass is cured under heavy pressure at a definite temperature for a certain time. This gives a tire that is remarkable on account of its strength, wearing qualities and flexibility. Although it is probably more flexible than any other material of equal strength, it is not perfectly elastic; hence, each time a section of such a tire is bent, energy appears at that section in the form of heat. This heat is conducted to the adjacent parts, so that the tire temperature rises rapidly immediately after starting the tire, and then less rapidly to some maximum value where it remains so long as the operating conditions do not change. This maximum temperature is reached when the generation of heat is just balanced by its dissipation to the atmosphere. The first of these two factors is influenced by

(1) Amount of Flexing
  (*a*) Load

[1] Professor of heat-power engineering, Cornell University, Ithaca, N. Y.

(*b*) Inflation-pressure
(*c*) Size of tire (chiefly sectional diameter)
(*d*) Supporting surface (flat, round, rough, smooth)
(*e*) Torque
(*f*) Side-thrust

(2) Rate of Flexing
(*a*) Speed of vehicle
(*b*) Circumference of tire

(3) Kind of Tire
(*a*) Size
(*b*) Design (thickness in particular)
(*c*) Fabric
(*d*) Compound
(*e*) Building
(*f*) Curing
(*g*) Previous use

(4) Sunshine

(5) Tread Slippage

The rate at which the heat produced is dissipated is regulated by

(1) Atmospheric Conditions
(*a*) Temperature
(*b*) Wind
(*c*) Moisture

(2) Speed

(3) Stops
(*a*) Frequency
(*b*) Duration

(4) Supporting Surface
(*a*) Temperature
(*b*) Material

(5) Mounting on Vehicle
(*a*) Mud-guards
(*b*) Nearness to exhaust
(*c*) Kind of wheel

(6) Kind of Tire
(*a*) Size
(*b*) Thickness
(*c*) Material
(*d*) Previous use
(*e*) Nature of external surface

(7) Artificial Cooling

Some of these factors are of only minor importance, while others are vital. Those of the utmost importance are

(1) Speed
(2) Load
(3) Inflation-pressure
(4) Length of run
(5) Kind of tire
(6) Atmospheric temperature
(7) Sunshine
(8) Supporting surface

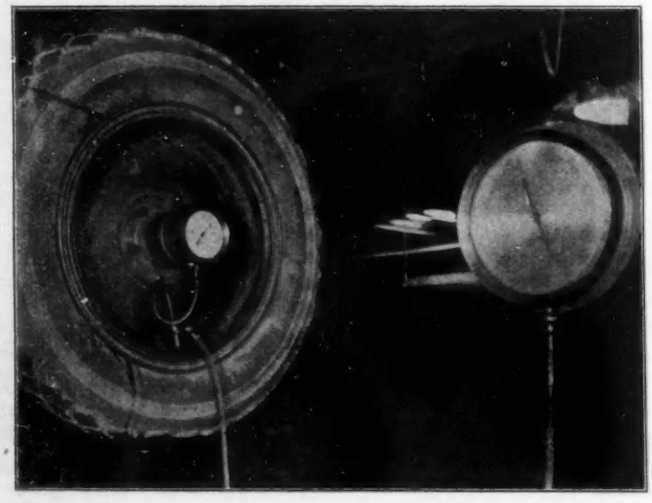


FIG. 1—GENERAL VIEW OF THE 40 X 8-IN. TIRE MOUNTED ON TESTING MACHINE SHOWING THE PRESSURE GAGE FASTENED TO THE HUB OF THE WHEEL AND THE LARGE STANDARD TEST-GAGE CONNECTED TO THE TIRE FOR DAILY CALIBRATION OF THE PRESSURE GAGE

A glance at these factors will indicate that it is not always easy to answer the common question, How hot does a tire become? Furthermore, a little consideration given to the question, How is the best way to determine this temperature? will show that this is a matter that cannot be answered easily. A search of the scientific literature yielded almost no information concerning the temperatures attained by pneumatic tires or the methods of measuring these temperatures. It was therefore necessary to develop methods of making such measurements.

From the beginning of the experiments it was felt that two or more independent methods of determining the tire temperatures should be used, if possible, to have a check on the results. One method that appeared to be accurate and reliable was the pressure-volume method or, in other words, measuring the initial temperature and the increase of the air pressure and volume very accurately and then calculating the temperature of this air in the tire. The question of how to determine the pressure was next in order. A detachable-gage method could not well be used as the leakage of air each time the connection was made and broken would be too serious. It was therefore necessary to use a stationary gage with some form of special connection to the rotating wheel, or mount the gage upon the hub of the machine so that it would turn with the tire. This last method was used very successfully. The wear on the gages is appreciable but not nearly so much as had been feared, especially by the gage manufacturers. Some gages are in fairly good shape after having been turned over more than 6,000,000 times

Fig. 1 shows a tire and its attached gage mounted on the testing machine. The gages were taken off and calibrated frequently by the usual dead-weight tester. They were also checked in place at the beginning of each run by the large portable standard-gage shown at the right of the illustration. This check was made also for the reason that it is essential that the initial pressure be obtained as accurately as possible, since all subsequent calculations are based upon it. To connect this large portable standard-gage with the tire under test it was necessary to design and build a special valve-opener so that the connection might first be made to the valve-stem and then the valve itself opened without losing any air. With proper attention paid to the gasket in this special valve-opener it proved very satisfactory.

Fig. 1 also shows how the tires were mounted for these tests. The cast-iron pulleys by which the tires are driven are about 45 in. in diameter and a suitable framework holds the tires in position on top of these pulleys. A known load is applied by weights to the axle on which the wheels are mounted.

LEAKAGE CORRECTIONS

There is always bound to be more or less leakage from any inner tube. This leakage depends upon a number of factors, such as the composition, thickness, temperature, age, and previous use of the tube, and the pressure of the air inside it. It is therefore necessary that the leakage shall be determined carefully for each run, thus giving the leakage under the complex conditions just as they exist.

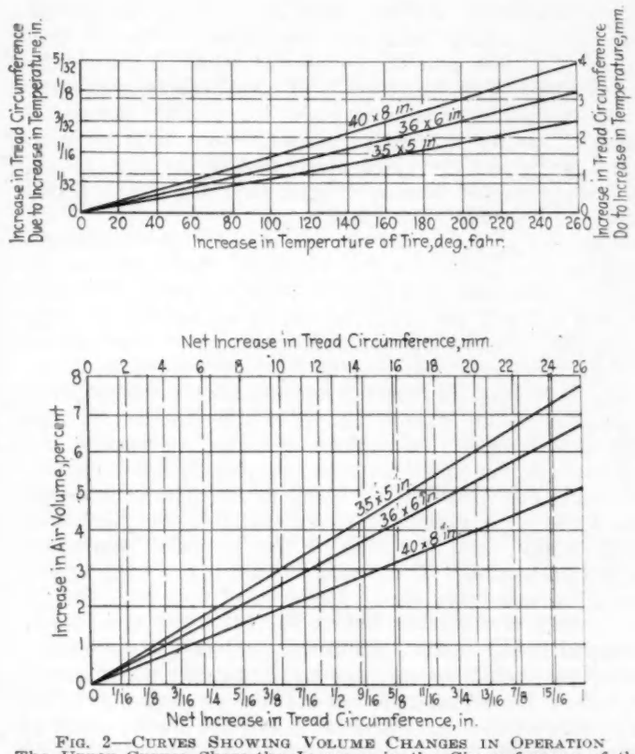

Increase in Tread Circumference Due to Increase in Temperature, in.
Increase in Tread Circumference Do to Increase in Temperature, mm.
40 x 8 in.
36 x 6 in.
35 x 5 in.
Increase in Temperature of Tire, deg. fahr.
Net Increase in Tread Circumference, mm.
Increase in Air Volume, per cent
Net Increase in Tread Circumference, in.

FIG. 2—CURVES SHOWING VOLUME CHANGES IN OPERATION
The Upper Curves Show the Increase in the Circumference of the Tread Due to the Thermal Expansion of the Tread and the Carcass, while the Lower Set Shows the Percentage of Increase in the Air Volume for Various Increases in the Tread Circumference Resulting from the Stretching of the Tire

The best way to make the leakage correction is to determine the average rate for the 24-hr. period following the start of the test. If this rate is small, as it usually is, the distribution of it may very properly be made on the basis of time alone. If it is appreciable the additional factors of temperature and pressure should be introduced in its distribution. Special effort was made to secure correct leakage corrections in all of these tests. A very close check was obtained on the observed leakage of one old tube by taking the pressure readings each hour during a 6-hr. run and the 18 hr. following it, then calculating the leakage on the assumption that it would be proportioned to the absolute temperature of the air in the tube and to the square root of the gage pressure. This method of distribution proved to be very satisfactory. Special curves were prepared to facilitate its application. In obtaining the 24-hr. leakage rate it will be found that usually the temperature and volume of the air in the tire are not the same at the end of this period as they were at the beginning. This necessitates that these values shall be determined and the proper corrections applied.

VOLUME CHANGES DURING OPERATION

Soon after beginning this work it was found that a pneumatic tire changes its volume very appreciably with variations in pressure, temperature and use. Various means of measuring this expansion were tried, the most convenient and accurate one being the measurement of the longitudinal tread circumference by a steel tape After the increase in tread circumference has been determined, calculations may then be made to show the corresponding change in the volume of any tire whose cross-sectional dimensions are known. Fig. 2 shows such relations for three different sizes of tire. Fig. 3 shows directly the temperature corrections that are due to changes in tire volume, for various initial temperatures and pressures. The temperature corrections for the change in volume are surprisingly large for the first day's run, being as much as 15 deg. Fahr. for a 40 x 8-in. tire in some cases, while the corrections on subsequent days would be only from 3 to 6 deg. It is also very interesting to note that after the tire has been run for a considerable mileage and then deflated and left to stand for an appreciable time, it will also nearly recover its original volume. When a tire of this kind is again used its volume will increase very materially during its first run after its long rest, just as a new tire would do.

TIRE THERMOMETERS

Soon after attempting to ascertain the best ways to measure tire temperatures, we believed that a successful tire thermometer might be designed and built. There would be two advantages in such a thermometer. In the first place, if it could be built to stand up under operating conditions and at the same time be reliable and not too much trouble to install, it would be the means used in all future tests to determine tire temperatures. On the other hand, if it were only partially successful it certainly would be worth while to have one solely for the purpose of obtaining the actual temperature of the air in the tire at the beginning of each test. This initial

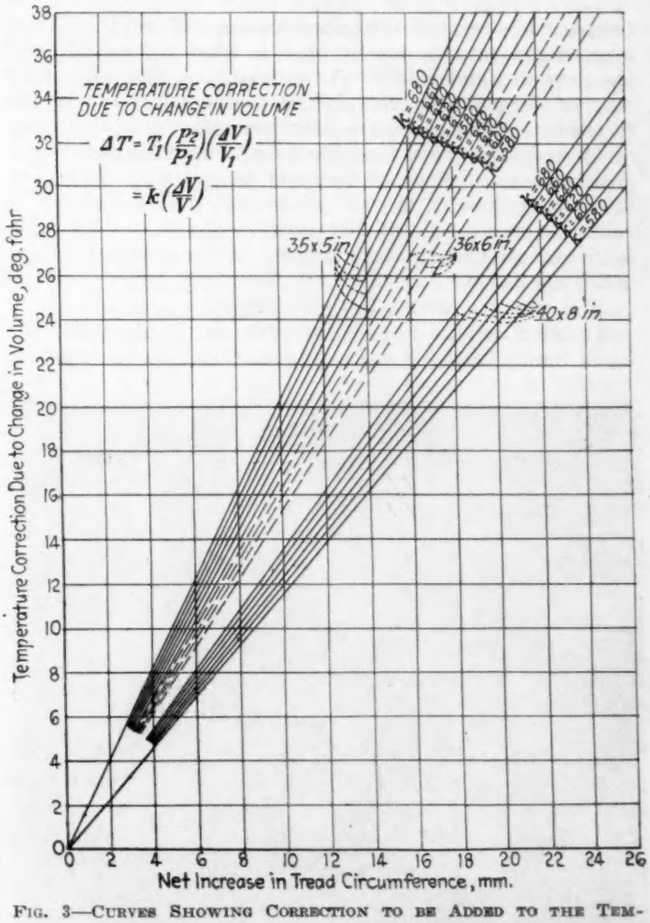

TEMPERATURE CORRECTION DUE TO CHANGE IN VOLUME
$\Delta T = T_1\left(\frac{P_2}{P_1}\right)\left(\frac{\Delta V}{V_1}\right)$
$= k\left(\frac{\Delta V}{V}\right)$
35x5 in.
36x6 in.
40x8 in.
Temperature Correction Due to Change in Volume, deg. fahr
Net Increase in Tread Circumference, mm.

FIG. 3—CURVES SHOWING CORRECTION TO BE ADDED TO THE TEMPERATURES AS CALCULATED FROM THE INCREASE IN PRESSURE
V_1 = Initial Volume of the Air in the Tube
ΔV = Increase in Volume of the Air in the Tube
P_1 = Initial Absolute Pressure of the Air in the Tube
P_2 = Final Absolute Pressure of the Air in the Tube
T_1 = Initial Absolute Temperature of the Air in the Tube
ΔT = Temperature Correction

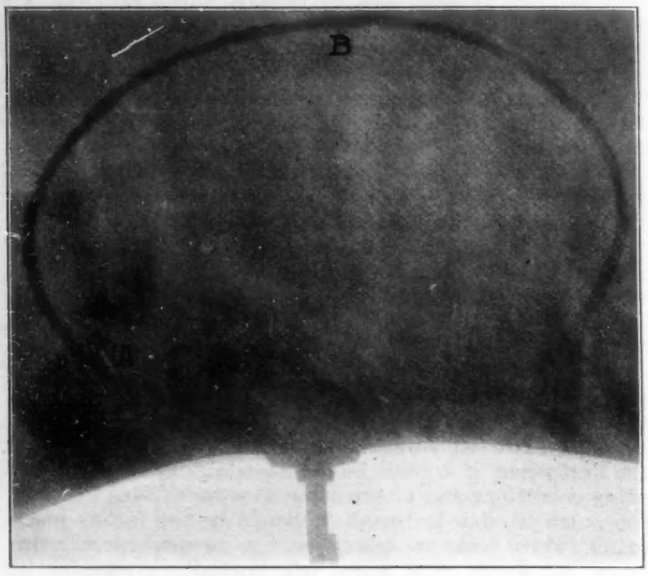


FIG. 4—X-RAY PHOTOGRAPH OF A SIDE VIEW OF PART OF A 40 X 8-IN. INNER TUBE WITH THERMOCOUPLES AT *A* AND *B*, EACH KEPT IN POSITION BY WRAPPINGS OF PIANO WIRE THAT ARE SOLDERED TO THE STEM

temperature is very important because all of the subsequent temperatures depend upon it when calculated from the pressure and volume measurements. The only other way of determining this initial temperature of the air in the tire is by placing a thermocouple inside the tube; or by keeping a record of the room temperature for several hours preceding the test and determining the lag of the temperature of the air in the tire with reference to room temperature. At the time mentioned we had not been able to make a satisfactory thermocouple to place inside the tube.

TUBE THERMOCOUPLES

We tried various ways before getting the thermocouple wires inside the tube so that there would be no leakage,

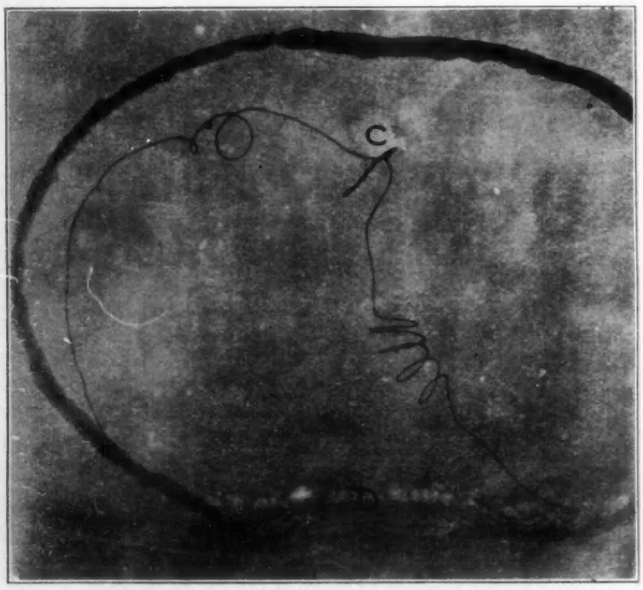


FIG. 5—X-RAY PHOTOGRAPH SHOWING A SIDE VIEW OF PART OF A 36 X 6-IN. INNER TUBE WITH THERMOCOUPLES HELD NEAR THE CENTER AT C AND THE BOTTOM AT D BY CORDS ATTACHED TO THE PIANO WIRE

the installation correct electrically, the construction strong, the couple held near the center of the air-space inside the tube, and the couples attached to the regular valve-stem. This last item is of considerable importance since it means the elimination of the trouble and annoyance of having to prepare a special tube with its extra valve-patch and the extra hole through the rim, as well as the additional trouble of mounting the tire and tube having this extra valve-stem.

Fig. 4 is an X-ray photograph of a 40 x 8-in. tube containing two thermocouples, one near the center of the tube at *A* and one near the bottom or rim at *B*. This type is very rugged mechanically, as shown by the fact that each one survived the splicing operation without distortion, but the heat that may be conducted from the couple itself by having the couple wires wrapped to the insulated supporting piano wire is a possible objection to this type. Fig. 5 is another side-view of an X-ray photograph of a tube which was taken after the couples in this 36 x 6-in. tube had been run during many tests. The couple near the center *C* is supported by an invisible cord that runs horizontally from one side of the wrapped supporting wire to the other. The bottom couple *D* has been broken from its supporting cord. The coils of fine thermocouple wire were symmetrical before the tube was spliced and inserted in the casing. However, it should be noted that despite its rough usage during splicing the center couple is still in its proper position. This is a very good type of construction as it is rugged and the heat conducted away from the couple is a minimum. With this type we obtained some very satisfactory checks on the temperature as obtained by the pressure-volume method.

CONVECTION CURRENTS

The low readings obtained from the tire thermometers and the tube thermocouples as compared with the temperatures calculated from the pressure and volume puzzled us very much. To eliminate the possibility of moisture getting into the tubes from the compressed air, a special separator containing calcium chloride was made and used when inflating each tube. By this means and also by samples of air drawn from the inflated tires we satisfied ourselves that the amount of moisture inside the tubes was very much less than that required for saturation. We were now sure that our calculated temperatures were correct, but we could not believe that the small wires used in the thermocouples would conduct away enough heat to cause the low readings obtained from them.

We next began the investigation of the effect of the convection currents inside a hot tube when standing still and when running. This proved to be very illuminating. We had always been reading the temperature from the inside couple when in a position some 30 deg. from the bottom (see Fig. 6) as this was the position in which the tires were always stopped to have the gage exactly right to obtain its correct reading. We now compared the couple readings in this position with those of the same couple in positions near the top to which we would quickly turn the tire. This gave a difference that usually would be 5 deg. or more. It is not easy to obtain this difference correctly as the tire must stand in one position long enough to enable the couple to acquire the temperature of the air in that position; then the time must be noted when the reading is taken to correct for the cooling that occurs after taking the reading in the first position. However, we did establish to our own satisfaction the existence of the convection currents shown by Fig. 6 for a hot tire that has just been stopped.

Using a set of collecting rings made of the same material as the couple wires themselves, we were next able to determine while the tire was running the difference in temperature readings between the couple near the rim and the one near the center of the tire. This difference was found to be large as will be shown later. The rotation of the tire causes very rapid convection currents in the transverse section of the tire. This also will be discussed more fully later. We were convinced that the thermocouples are subject to appreciable correction due to convection currents, and that the magnitude of these corrections depends upon the position of the couple relative to the center of the tube, whether the tire is running or standing still. These same convection currents would account for a considerable part of the discrepancy still found to exist in the case of the tire thermometer in a well with many fins on it. This information, coupled with that concerning the heat conduction, which was such a big factor with the tire thermometer, now gave us peace of mind regarding our temperatures as obtained by the pressure-volume method, and made us feel certain that for comparing the temperatures of different designs of tire this is the best method of which we have any knowledge.

Detachable Thermocouples

After having experimented with tube thermocouples and realizing fully some of the serious difficulties that cannot be overcome on account of their being inside of the tube, it was felt that it would be worth while to experiment with detachable couples. By this term we mean couples that are inserted in small holes drilled through the tread to the cushion, breaker or carcass as desired. After making satisfactory holes through the tread, it is necessary to have a couple made of very fine wire mounted on the end of a small insulating plug that can be inserted in the hole. Wood and hard rubber are suitable but the latter is preferred because it is not broken so easily.

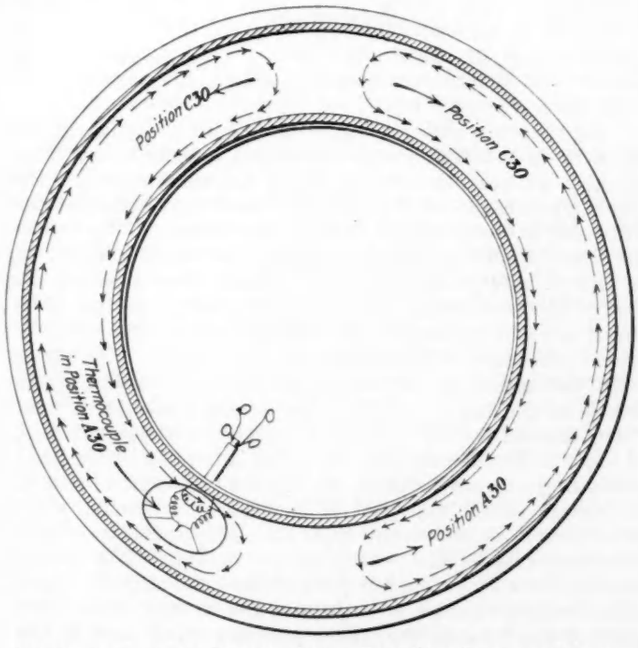


Fig. 6—Convection Currents in a Hot Tire Immediately after Stopping

The Dotted Lines Indicate the Path and Arrowheads the Direction of the Convection Currents when the Tire Is Standing Still. All Temperatures Were Obtained by the Pressure-Volume Method with a Load of 2500 Lb. at a Speed of 30 M.P.H.

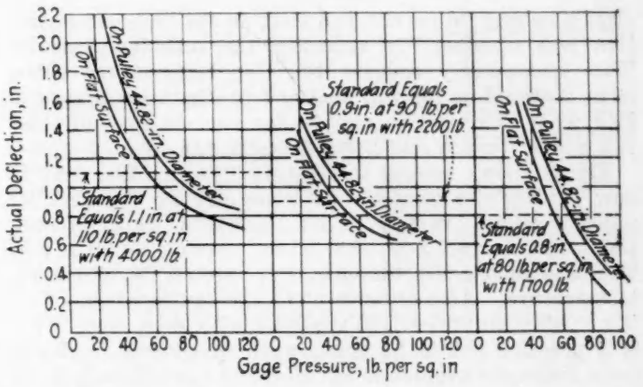

Actual Deflection, in.
Gage Pressure, lb. per sq. in
On Pulley 44.82-in. Diameter
On Flat Surface
Standard Equals 1.1 in. at 110 lb. per sq. in with 4000 lb
Standard Equals 0.9 in. at 90 lb. per sq. in with 2200 lb
On Pulley 44.82-in. Diameter
On Flat Surface
On Pulley 44.82-in. Diameter
On Flat Surface
Standard Equals 0.8 in. at 80 lb. per sq. in with 1100 lb

Fig. 7—Deflections of Three Sizes of Tire Having Various Inflation-Pressures when Supported by Flat and Curved Surfaces

This type of detachable couple can be inserted immediately after stopping the tire and the temperature indicated by the potentiometer will rise to its maximum value very quickly after insertion. It is not, however, an instantaneous process and the reading must not be made too quickly after the insertion of a cold plug, as it may require at least 30 sec. to reach the maximum temperature. With every care that we could exercise in all particulars it was still found that for some unknown reason this method would give occasional readings which were 10 or 15 deg. too high or too low to plot a smooth curve. Such cases, however, were very infrequent and our experience indicates that this is a method of great value, especially as a supplement to the pressure-volume method. Obviously one of its greatest advantages is that it enables the temperature of the stock itself to be measured and our investigations have shown that this temperature is considerably higher than the temperature of the air inside the tube. The other chief advantages of this system are the simplicity of the apparatus and the ease of renewal of the couple. It is also obvious that it has one disadvantage, namely, the injury to the casing resulting from drilling a hole through the tread. For laboratory-test tires this in itself is not a serious matter because there is no sand or dirt to work its way inside the carcass. It seems likely that there may be an appreciable correction to be added to the readings obtained from couples inserted in a hole in the rubber or carcass. This correction is due to heat conduction through the wires from the couple, and is greater the shallower the hole. This phase of the subject is now being carefully investigated by the research division of the Goodyear company.

Some Test Results

Before making any comparative temperature-tests it was necessary to determine the deflection of various sizes of tire when resting on the curved surface of the testing machine. By deflection of a tire we mean the vertical drop of any part of the wheel on which the tire is mounted as a result of applying a known load to the tire. This deflection causes the lower part of the tire to flatten until the contact area becomes sufficiently large to support the load with the air pressure existing in the tire.

Fig. 7 shows the results of deflection tests on three sizes of tire for various inflation-pressures, two kinds of surface and one load. These curves show what load is needed to give a normal deflection of the tire when mounted on the testing machine. For the runs that were made on the 40 x 8-in. tires this machine was not

strong enough to permit full load, so the full-load deflection was obtained by reducing the inflation-pressure. This undoubtedly reduces the tire temperature below what it would be for full load and full inflation-pressure. Just what this relation may be for various sizes of tires is a matter that is still being investigated.

Fig. 8 shows several interesting things. The first is how rapidly the temperature rises during the first 60 miles, then less rapidly to its maximum, which is near 150 miles, for an 8-in. tire when running at 30 m.p.h. The smaller the tire the sooner it reaches its maximum temperature. Also observe what the temperature effect is of using an undersized rim on a 40 x 8-in. tire. This is a practice not to be encouraged in general, and one to be distinctly avoided in hot climates. It will be noticed how fast the temperature of this size of tire rises with decreasing inflation-pressures. For the load of 2500 lb. the lowest pressure, 38 lb. per sq. in., represents a deflection nearly 60 per cent more than normal. This is what many tires sometimes have to endure. These curves indicate that the "air thermometer made out of a tire" may be entitled to the high rank usually accorded this type of thermometer.

Fig. 9 shows the temperatures of the various parts of an 8-in. tire as obtained by the several methods described. The reason for the inside couple near the center of the tube giving values lower than those obtained from the pressure and the volume is probably largely due to heat conduction from the type of couple used, shown by Fig. 4, and to the convection currents. These readings from the inside couples were all obtained while the tire was running, except those taken after 5½ hr. of the test when the tire was stopped. Attention is called to the very rapid drop in temperature of the eighth ply and of the cushion in the tire immediately after stopping, at the end of 150 miles. This is a 12-ply tire with a thick tread. This test shows, as did many other similar to it, that the air in the tube is some 15 or 20 deg. cooler

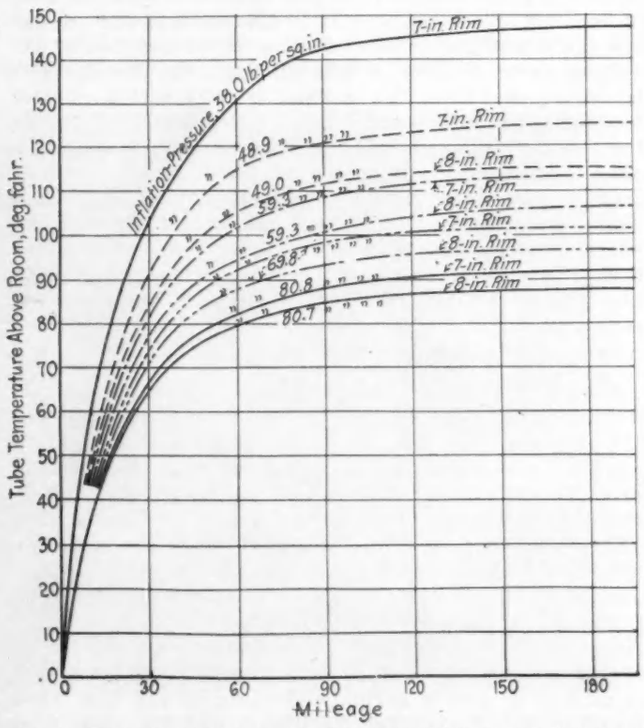


FIG. 8—TEMPERATURES OF A 40 X 8-IN. TUBE ABOVE THE ROOM FOR VARIOUS MILEAGES AND INFLATION-PRESSURES AND TWO-RIM SIZES

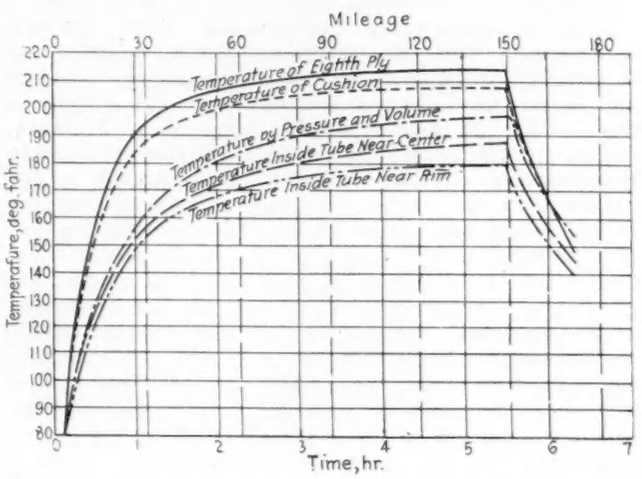


FIG. 9—TEMPERATURES OF VARIOUS PARTS OF A 40 X 8-IN. TIRE AS OBTAINED BY VARIOUS METHODS, THE ROOM TEMPERATURE IN THIS CASE BEING 90 DEG. FAHR.

than parts of the casing. It also shows how quickly the high temperatures are reached by those parts of the tire in which the heat is produced, so that long distances do not need to be covered to produce temperatures that may be injurious to the carcass.

ARTIFICIAL COOLING

For those sections of the Country where there are long periods of very hot weather it is undoubtedly true that some simple means of keeping large truck-tires cooler than they are under present conditions would be very valuable. It was therefore one of the purposes of these experiments to ascertain if possible some means of doing this. The most successful method of artificial cooling investigated was that in which a small quantity of water is placed inside the tube before inflating it with air. Many such experiments, beginning in 1919, have been run and in all cases the reduction of the average tire-temperature by water has been very noticeable. The hotter the tire the greater this effect, for reasons that will be discussed later.

The theory which prompted trying water inside of the tube is this. First, we should expect a certain reduction of heat generation because of the reduced flexure of the casing by reason of the increased pressure inside of the tube due to the pressure of the water vapor. This vapor-pressure would be small, but nevertheless would act as a sort of safety-valve in under-inflated tires because the hotter the tire the greater would be such pressure. The vapor-pressure rises faster than the air pressure for a given increment of temperature.

In the second place we should expect that the vapor inside of the tube would transfer a large amount of heat from the hot portions of the tube to the cooler parts of it since as the tire rotates the water is kept in a thin band extending entirely around the tread portion of the tube. A section of the top part of a rotating tire with some water in it is shown in Fig. 11. That portion of the tube covered by the water is the hottest. The water absorbs heat from the hot part of the tube and the vapor thus formed carries a large amount of heat from this part of the tube to the cooler portions lying next to the rim and sidewalls on which condensation takes place. There is a very rapid circulation of the air and vapor in all transverse sections of the tube, as indicated by Fig. 10, due to the difference in temperature between

the tread and bead sections of the tire. The faster the tire rotates the more rapid is this circulation. Thus it is easy to conceive of an extremely rapid circulation in every transverse section of a rapidly rotating tire whether it has vapor in it or not. The addition of water-vapor produces more rapid circulation as it increases the difference in densities for equal temperature-differences. It is, however, in the vastly superior heat-carrying capacity of a wet vapor, as compared with dry air, that we should expect to find the main advantage of the vapor. The delivery of more heat to the cooler parts of the tube lying next to the rim and sidewalls means increasing the ability of the tire to dissipate heat to the atmosphere. If this be true, we should find a very marked decrease in the temperature of the hottest parts of the tube, which always fail first, and an increase in the temperature of the coolest parts of the tube, which never fail from high temperature. The average tube-temperature should also be lowered in proportion as the ability of the tire to dissipate its heat is increased. This would be best determined by the temperature of the air in the tube, as the average

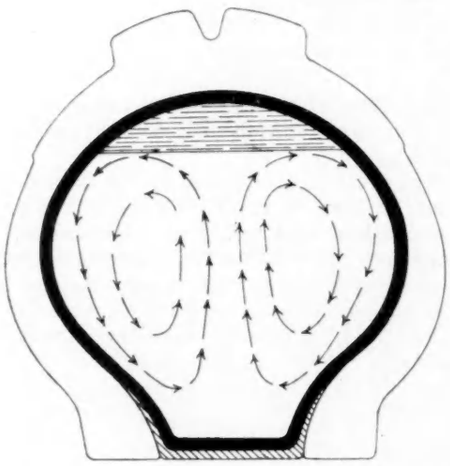


FIG. 10—CROSS-SECTION OF A ROTATING TIRE WITH ABOUT 10 PER CENT OF THE TUBE VOLUME FILLED WITH WATER
The Arrows Show the Path of the Convection Currents

temperature of the tire cannot be so nearly measured by any other means.

In the third place, we should expect a cooling effect by reason of the absorption of heat by the liquid itself, until this liquid becomes heated up to the same temperature as the tube. Here we should expect a cooling effect that would depend upon the amount of liquid used and the distance run without stopping. On the other hand, the effect of the vapor will be independent of the amount of liquid used. The experimental evidence will now be presented to substantiate this theory.

Fig. 11 shows clearly the cooling effect of water inside the tube of a 40 x 8-in. tire in amounts varying from 5 to 25 per cent of the air volume of the tube or from about ¾ to 3½ gal. of water. The larger amounts are advantageous only during the first few hours of the run, as the temperatures with water in the tube all finally approach the same value. This wet-tube temperature is seen to be very appreciably lower than when using the dry tube. These curves were all taken with the same tire, tube, load and speed and also with the same inflation-pressure which was kept low to give a flexure about 30 per cent greater than normal.

Fig. 12 shows what portion of the total pressure in the tubes of two badly under-inflated tires is due to the

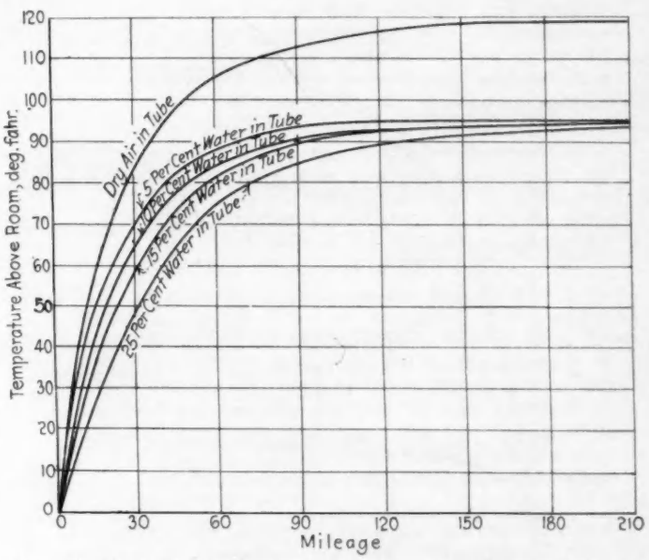

Temperature Above Room, deg. fahr.
Mileage
Dry Air in Tube
5 Per Cent Water in Tube
10 Per Cent Water in Tube
15 Per Cent Water in Tube
25 Per Cent Water in Tube

FIG. 11—TUBE TEMPERATURES RESULTING FROM VARIOUS AMOUNTS OF WATER IN THE TUBE

vapor. For each tire it will be noticed that the total pressure is slightly greater with the dry tube until about 30 miles have been run. From that point on the temperature has become high enough so that the vapor-pressure more than compensates for the lower air-pressure in the

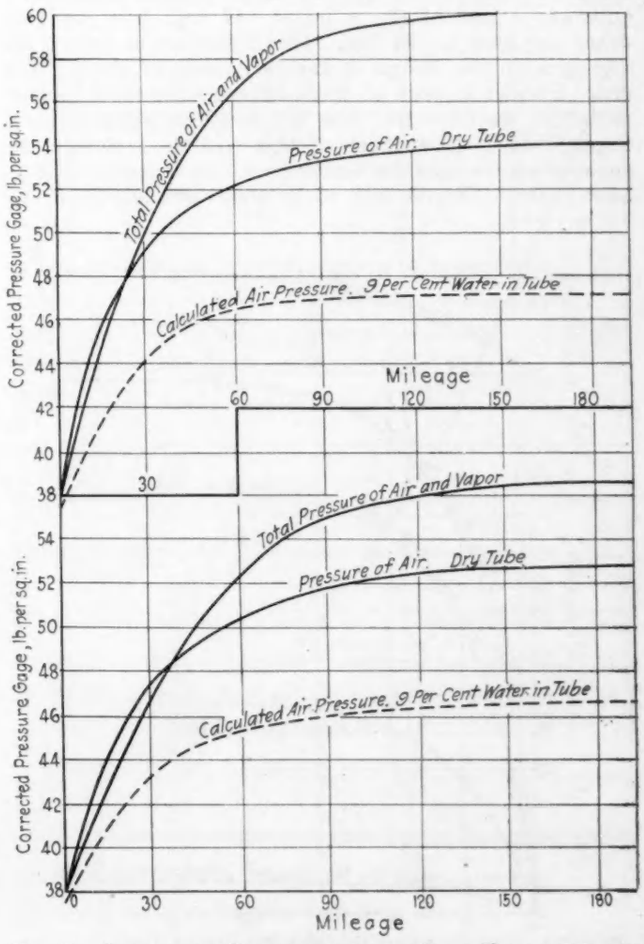


FIG. 12—COMPARATIVE PRESSURES IN THE SAME TIRES WITH AND WITHOUT WATER IN THE TUBES

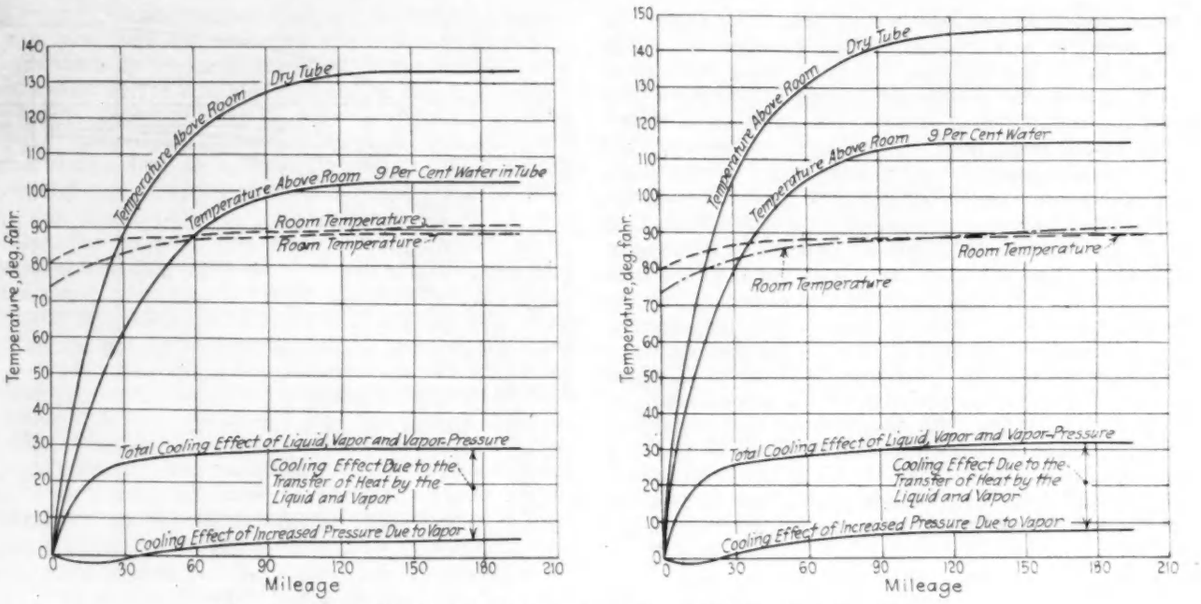

Temperature, deg. fahr.
Mileage
Dry Tube
Temperature Above Room
Temperature Above Room 9 Per Cent Water in Tube
Room Temperature
Room Temperature
Total Cooling Effect of Liquid, Vapor and Vapor-Pressure
Cooling Effect Due to the Transfer of Heat by the Liquid and Vapor
Cooling Effect of Increased Pressure Due to Vapor
Dry Tube
Temperature Above Room
Temperature Above Room 9 Per Cent Water
Room Temperature
Room Temperature
Total Cooling Effect of Liquid, Vapor and Vapor-Pressure
Cooling Effect Due to the Transfer of Heat by the Liquid and Vapor
Cooling Effect of Increased Pressure Due to Vapor
Temperature, deg. fahr.
Mileage

FIG. 13—CURVES GIVING AN ANALYSIS OF THE EFFECT OF WATER IN THE TUBE

wet tube due to its lower temperature. In Fig. 13 the wet tubes are seen to be about 30 deg. cooler than the dry ones after 90 miles have been run. At 30 miles this difference is about 25 deg. With these tires badly under-inflated one of the dry tubes reaches a temperature above that of the room of 147 deg. fahr. and the other one goes to 134 deg. This difference is due to the variation in the design of the two casings. With 9 per cent of water in each of these tubes in the same casings as before we have the tube temperatures reduced more than 30 deg. How much of this cooling is due to the vapor-pressure may be found from the bottom curve in each chart. This is seen to be about one-fourth of the total cooling effect, showing that the vapor must be given the credit for most of the benefit derived from the water in the tube.

The curves given at the bottom of Fig. 14 are extremely valuable as they help to explain so much that was at one time very puzzling and annoying. Reference has been made to the fact that the tire thermometers always gave temperatures much lower than those obtained by calculation from the pressure and volume measurements. With water in the tubes the tire thermometers would for many tests give higher readings than with the dry tubes. I believed that this was because the vapor caused a greater reduction in the correction of the tire thermometer than

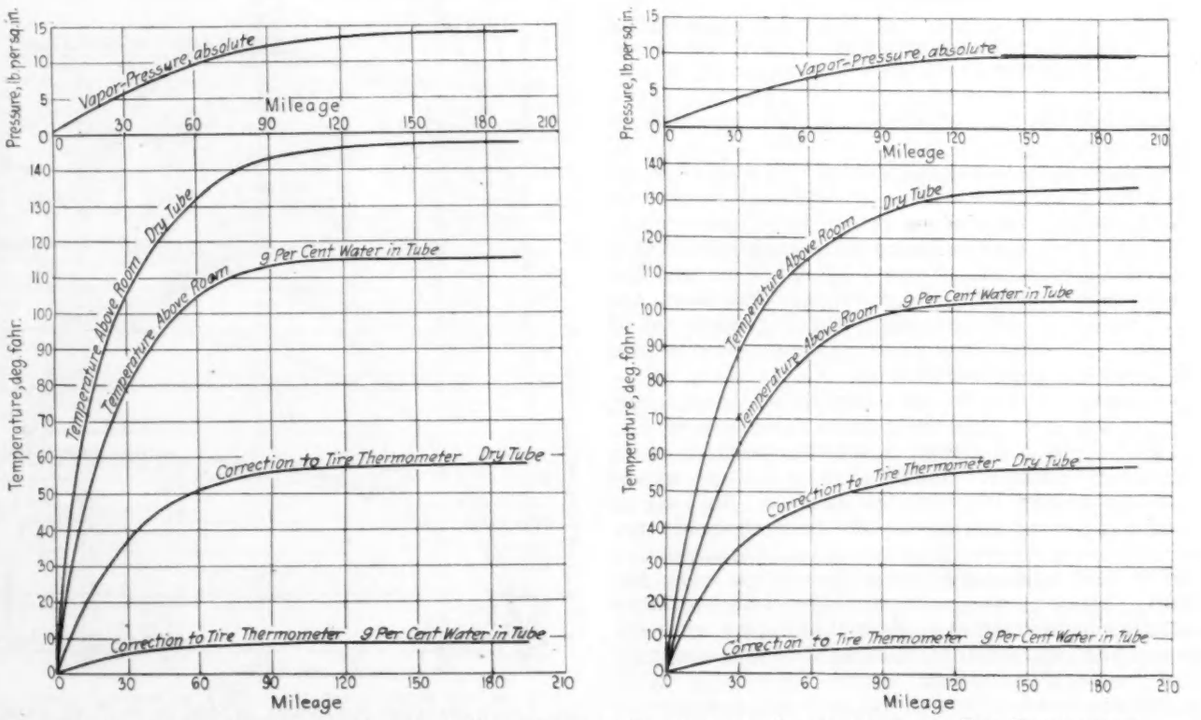


FIG. 14—CURVES SHOWING THE EFFECT OF WATER VAPOR IN REDUCING THE CORRECTION OF THE TIRE THERMOMETER

SIDE GUIDE AND GRIPPER

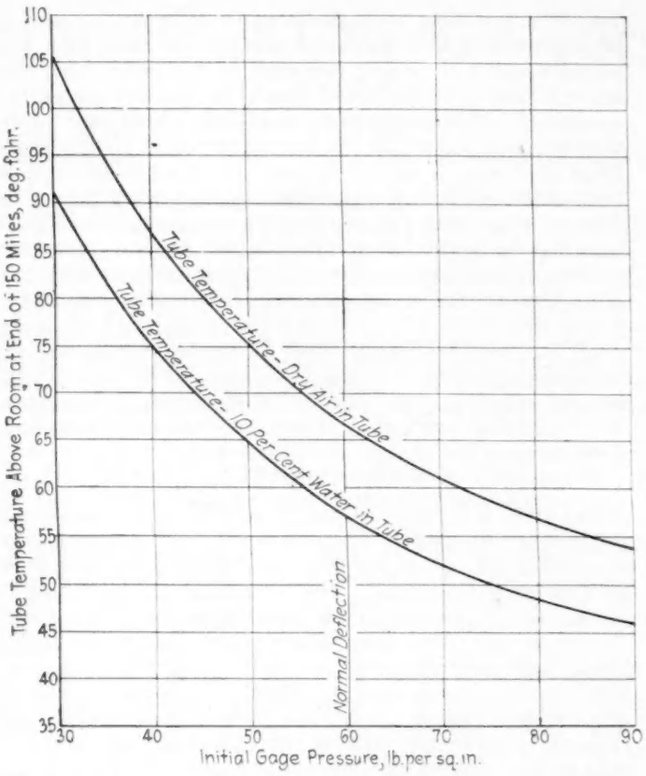

Tube Temperature Above Room at End of 150 Miles, deg. fahr.
Initial Gage Pressure, lb. per sq. in.
Tube Temperature - Dry Air in Tube
Tube Temperature - 10 Per Cent Water in Tube
Normal Deflection

FIG. 15—TEMPERATURE EFFECT OF UNDER-INFLATION ON A SMALL TRUCK-TIRE WITH AND WITHOUT WATER IN THE TUBE

it caused in the reduction of the temperature of the tube. To prove this was not easy. I have already mentioned the large correction of the tire thermometers due to heat conduction from the thermometer well. With wet vapor surrounding this well instead of dry air the amount of heat delivered to it would be much greater; hence we should expect a large reduction in the correction of the instrument. This made it imperative to check very carefully, as already described, the amount of moisture in the air when we were supposed to be using dry air.

In Fig. 15 may be seen the serious temperature effects of under-inflation on dry and wet tubes in a 36 x 6-in. tire. Even for this size of tire the cooling effect of the water is very marked, but is not as great as with the 8-in. tire. Just how rapidly the temperature increases with the size of tire is clearly shown by Fig. 16. This is chiefly due to the increase in the thickness of the walls of the casing as the size increases. It is obvious from this chart that ordinarily no artificial cooling is needed for tires 6 in. or less in diameter, but as we go to 8 in., and above, anything that will keep the tire cooler should be used if it is not troublesome in its application. Putting a small amount of water inside a tube is a simple matter and there is nothing further to do about it until the tire is to be used in freezing climates, when the tube should be taken out and drained. There is no change in the riding qualities of the tire by using a small amount of water. There appears to be no objection to its use and the certainty of its cooling effect on the tube makes it deserving of a trial by all truck owners who operate large pneumatic tires at high speed over long distances in hot climates.

GENERAL CONCLUSIONS

From these experiments it may be deduced that:

(1) The measurement of the increase in the air pressure of a tire is a very accurate and reliable means of determining the average tube-temperature, provided proper precautions are taken to know whether the air is saturated and to have accurate measurements of pressure, volume changes, leakage and initial temperature

(2) Convection currents inside the hot tube are very large and may produce a large correction to any temperature-measuring apparatus that records only the particular temperature at some definite region, which is small in comparison with the whole cross-sectional area of the tube

(3) These convection currents are due to the variation in density of the air in contact with the hot and cool portions of the tube, combined with the force of gravity and that due to the rotation of the wheel. The first of these forces causes the convection currents to flow in the longitudinal direction of the tube when the tire is standing still, and the second causes much stronger currents in a transverse section of the tube when running

(4) Tire thermometers of the type described are not very well suited to any tube-temperature measurements except the initial one, on account of the corrections due to the convection currents and the still greater correction due to heat conduction to the cool part of the tube to which the well must be clamped

(5) Thermocouples placed inside the tube and mounted so that they will be held near the cen-

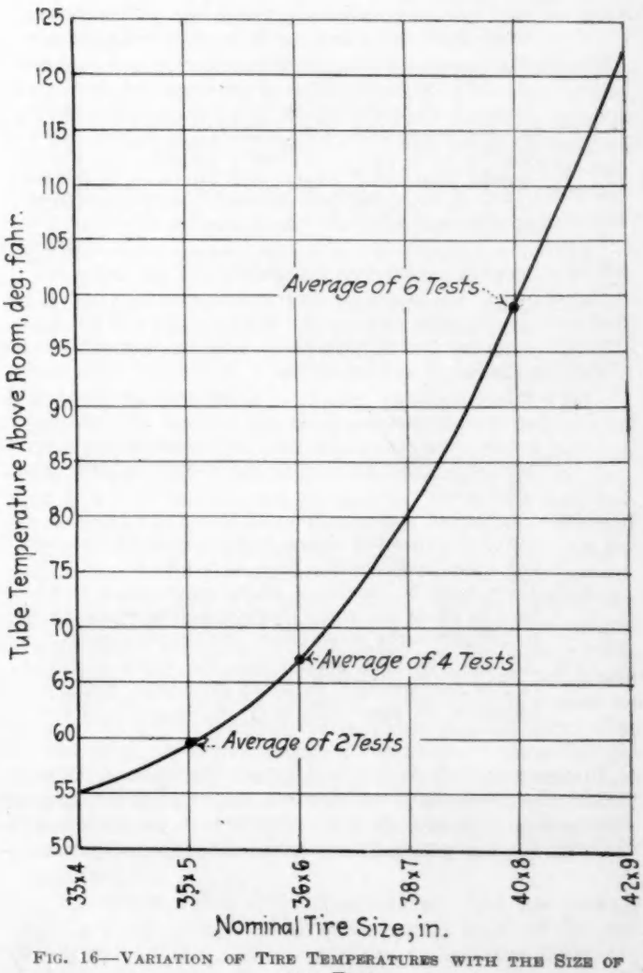


FIG. 16—VARIATION OF TIRE TEMPERATURES WITH THE SIZE OF THE TIRE

SIDE GUIDE AND GRIPPER

ter of the tube are rather frail and are likely to be injured or misplaced during the splicing of the tube. They are also subject to corrections due to convection currents and require considerable care and patience to make and install

(6) Detachable thermocouples of the type described are easily made and used. They are reliable when carefully used, and possess the very great advantage of giving fairly close to the correct temperature of the various parts of the tire that are hottest and whose temperatures are often most desired

(7) The detachable-thermocouple readings must be taken at very carefully measured intervals of time after stopping the tire as the hottest parts of the tire cool appreciably and rapidly immediately after stopping

(8) It appears likely that the detachable thermocouple should have a correction applied to its reading to compensate for the conduction of heat through the wires from the couple to the outside air. This correction has not been worked out completely as yet but will be greatest when this type of couple is used in holes of shallow depth

(9) The pressure in the tube does not begin to drop until a short time after stopping the tire, thus affording time for obtaining accurate pressure and volume readings

(10) The pressure-volume method combined with the detachable thermocouple one appears at the present time to be best suited to determining pneumatic-tire temperatures, as the results are more accurate, comprehensive and easily obtained than those from any other methods thus far developed

(11) For comparative tire-temperatures the results should be given in terms of temperature above the atmosphere surrounding the tire, as this factor is very important and variable. It is also essential to have the same loads, inflation-pressures, speeds, distances, supporting surfaces and sunshine in order to use comparative temperatures of different designs of the same size of tire

(12) The temperature of a tire increases very rapidly with its size due to the thickness of its walls

(13) High temperatures are destructive to tires but the relation between the life of a tire and its temperature for various compounds has not yet been established

(14) Small amounts of water, from 5 to 10 per cent of the air volume, used in the tube with the air result in a cooler tire, the difference in the temperature being marked in the case of a large hot truck-tire

(15) The use of water in tires of passenger-car size is not recommended, since their temperatures are not usually sufficiently high to justify it

(16) Care must be exercised when using water in the tube to drain the water from it before exposing it to temperatures much below the freezing-point

(17) All users of tires should note the rapid increase in tire temperature with the decreased inflation-pressure, so that they may prolong the life of their tires.

In conclusion, I desire to express the opinion that the study of pneumatic-tire temperatures is of much greater commercial importance and possibly of more scientific interest than is generally realized. A quick temperature-test of a tire may yield much more information than a long expensive test to destruction of the same tire. A temperature test is not, however, complete in itself for all tire testing, since tread wear, for example, requires another type of test, which, incidentally, can also probably be made better in the laboratory than on the road. Even after the correct temperatures of a tire shall have been determined, there is much research work yet to be done in order that the full significance of such information may be appreciated. This much, however, is sure: the rise in temperature of a tire is a direct and sensitive indication of the waste of energy due to its operation. The greater this loss of energy the faster the tire wears itself out and the more power is wasted to operate it. This loss can never be reduced to zero, but it can be kept low by selecting the most suitable materials and then very skilfully combining them according to the best design.

THE DISCUSSION

ELLWOOD B. SPEAR:—Only those who have endeavored to measure accurately the temperature of a pneumatic or a solid tire can appreciate the difficulties encountered by Professor Ellenwood. He is certainly to be congratulated on his success in his painstaking and important investigation. Tire manufacturers are making an intelligent and well-organized effort to give the consumer better value for his money. They will inevitably fail to get the best results, however, unless the consumer is ready to cooperate by taking proper care of his tires. I believe that one of the best methods of obtaining this cooperation is to demonstrate to the automotive engineer, the tire repairer and the consumer what happens to a tire in cases of overloading, under-inflation and fast driving. The determination of the temperature in the different portions of a tire offers a convenient means for the investigation of the effect of the design, as well as of the part played by the above-mentioned factors.

JOHN P. COE:—Engineers in the rubber industry are continually confronted with difficulties in scientific work due to the fact that the materials they are using are in a sense intangible compared with most of the materials used in the construction of automotive machines. Professor Ellenwood's work is all the more significant to tire engineers on that account. I have been very much interested in the data he has presented, as well as in the methods he has explained for measuring the temperatures developed, on account of the fact that we have experimented along very similar lines. Our research has not been as complete as Professor Ellenwood's, however, and is covered in most respects by his report. We use a slightly different arrangement for measuring the temperatures of the tire wall in that we attach our thermocouples to an awl point and are able thereby to insert them quickly into any part of the tire desired. We use small wire for thermocouple leads and solder the couple to the point of the awl. This outfit does not last indefinitely but is more durable than might be expected.

It has been very interesting to hear Professor Ellenwood's discussion of the effect of adding water to the air within the tube, inasmuch as we made this discovery ourselves without previous knowledge of his work. It is, however, evident from his report that he antedates us in the discovery.

The Car-Owner versus the Service-Man

By J. F. Page[1] Chicago Service Meeting Paper

STATING that there has been, and still is, too little mutual understanding, as well as too much bitterness and dissatisfaction between the automobile public and the service departments, the author outlines methods of improvement.

The service problem is considered under seven headings, which are amplified, and the service-man's problem is discussed with these headings as a basis, assuming that he has equipped himself with a trained personnel, space and adequate tool equipment and an effective system.

Fair and unfair service demands by car-owners are differentiated and a summary is made of some of the reasons that make satisfactory service impossible.

THERE can be no real and lasting benefit to either the car-owner or the service-man without mutual satisfaction in their business relations. If the owner expects perfection in the car and free service, the business of the service-station will not produce satisfactory results and there will be no profit. If the service-man is unreasonable, repair prices exorbitant and work imperfect, the public will neither patronize his shop nor buy the make of car represented by him. There has been and still is too little mutual understanding, as well as too much bitterness and dissatisfaction between the users and the handlers of automobiles. There is right and wrong on both sides.

The public gradually is learning that motor vehicles are complicated pieces of machinery, which are subjected to abuse and therefore require adjustments and repairs not covered by the purchase price. The average car-owner is slow to admit that a car should not run indefinitely with the addition of a little oil and fuel, and does not accept gracefully the normal repairs and loss of use of his car. On the other hand, the service-man must be brought to a sympathetic realization that the use of the car has become a necessity in the owner's life, and that the loss of the car's services may throw his business and social engagements out of joint. In the case of the truck-owner, the result may be a pecuniary loss. The vehicle, whether passenger-car or truck, must give a consistent performance at a reasonable cost to be satisfactory. These are generalities, but the need of patience and a realization of the inevitable on the one hand, and of proper equipment and a sincere effort to please on the other, are obvious, if the service-man is to accomplish his task and the owner is to be satisfied with his car and the service.

The Service Problem

To get a bird's-eye view of the service problem, it is necessary to consider the demands of the car-owner and the requirements of the service-station to fill those demands satisfactorily. Let us first review the demands of the owner and the sources of service complaints. There are reasonable demands and unreasonable ones. Reasonable demands are susceptible of satisfactory fulfillment, and should be met by the service department efficiently and satisfactorily. Unreasonable demands make it impossible to satisfy the owner and are the cause of the service-man's "grief." The reasonable demands of the owner include:

(1) Courteous and intelligent treatment
(2) Proper mechanical work
(3) Quick service
(4) Dependable promises
(5) Fair prices
(6) Correct and understandable bills
(7) A convenient location of the service-station

Courteous and intelligent treatment means much. In an efficient uptodate service-station, the car-owner expects to deal with a high-class attendant who evinces a real interest in him and in his car. He likes to discuss repairs with a man who knows what he is talking about, and who will use judgment and intelligence in taking orders. He expects the service-man to know whether the owner wishes his car kept in perfect condition regardless of expense, or whether he wants to spend as little as possible to keep it in fair operating condition. He expects the service-man to take time to discuss his problems, and not to hurry away as though the owner's troubles were of little moment. He expects to be given prompt attention, not by a man with greasy hands who wears overalls, but by one dressed in clean clothes who has a pleasant smile.

Proper mechanical work is, of course, the primary object to be attained, but is advisedly placed second on the list of the car-owner's demands because he comes in contact with the service salesman first and looks for proper results from the shop as a secondary matter. The two are equally important; the success of each depends absolutely upon the effectiveness of the other, while both are essential.

The time has arrived when the passenger-car and the truck are absolute necessities of social and business life. Until the day comes when every car-owner will also own an emergency vehicle, it will be demanded that the service-station use every possible means to eliminate delays and speed-up repairs.

With quick service goes the demand for a promise on delivery so dependable that engagements can be made and kept. Dependable promises are more important, by far, than speed in turning out the work. After his first disappointment at the loss of use of the car, the owner will resign himself to the necessary adjustment of his engagements; but when the promised time for delivery has arrived, nothing else will satisfy him. The failure of the service-station to fulfill his promise is, in his eyes, an inexcusable and most annoying blunder, be the reasons what they may. The car-owner will not be satisfied with any "hard-boiled" policy of refusing a promise, nor does he wish to telephone several times about the delivery. The service-man should not talk of "estimated" time for delivery, because this means *the* time to the car-owner, just as clearly as if the service-man had said "promised" time. The car-owner will pay little attention to the technical difference between the words "estimated" and "promised."

Fair prices are a difficult question. The car-owner's ideas are not always in agreement with those of the service-man. In fact, the average owner has very little conception of repair costs. His ideas of fair prices probably

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would put the best repair-shop out of business in a short time. The owner who does not know something about the construction of cars is hard to convince that the same job may require entirely different lengths of time on different makes, due to differences of design or accessibility. Nevertheless, the service department must know the costs and do the work according to the best and cheapest methods if the maintenance charges are to satisfy the car-owner. A fair-minded business-man will expect the prices of repairs to be based on adequate equipment, efficient workmen, good materials and business-like administration.

Correct billing is essential, yet the collection of cost data in a large shop is a prolific source of trouble, resulting in errors of both commission and omission. The terms used by the shop are Greek to many owners. The result of doubt regarding the correctness of the charges is slow pay, claims and adjustments, collection costs and much dissatisfaction. Billing, correctly and promptly done, is necessary to keep the car-owner satisfied and avoid troubles and complaints. This question opens the subject of estimates, flat prices, cash on delivery and the like. Sooner or later a definite policy must be established for repair work in the motor-car industry and the sooner the better. The present lack of uniformity of action and thought by the motor-vehicle distributor and the repair-shop manager is keeping the public in a state of discontent and uncertainty.

Convenience in regard to the location of the service-station has always been important to the owner, but it is a difficult problem for the distributor. Salesrooms as a rule are located in congested districts, where space is high in price and small in size. Many distributors have found it necessary to enlarge their service spaces to such an extent that they have been forced to locate the service-station at a distance from a point central and convenient for the owner. Inconvenience of location may result in repair work being taken to outside shops which are not always so well equipped to do the work as the distributor's own service department. In order to compensate for the inconvenience of location the service-station must give so much better service that the car-owners will be willing to travel the greater distance.

The Service-Man's Problem

Corresponding to the fair-minded owner is the conscientious service-man who knows what the customer expects and sincerely tries to give 100 per cent of satisfaction for every dollar he receives for service. His problem is to provide the three essentials, without which the demands of the owner cannot be met successfully: (*a*) trained personnel, (*b*) adequate space and tool equipment and (*c*) an effective system.

The first person with whom the car-owner comes in contact will be the service salesman. Psychology and human nature are brought out in the dealings of the owner with the service department. To the customer the service salesman is the company and the service will be looked upon favorably or otherwise, depending upon the impressions made by the service salesman perhaps more than upon any other one thing. It is the more or less intangible things that affect the owner's opinion as much as the actual job performed by the shop. The efficient and successful service salesman is a man who has had practical experience and possesses qualities of even temperament and tact. He must be a real salesman, continually selling the owner both the car and the service, and doing so very often under adverse conditions. No two persons are alike. The service salesman must be a student of human nature in addition to his other qualifications and meet the customer's demands for courteous and intelligent treatment. He must know whether the car-owner with whom he is dealing wants perfection, regardless of cost, or the least work at the least cost. Nearly every owner has particular whims and ideas of adjustments. Only by catering to these will the service-man please his customer. How often a shop makes standard adjustments, only to find that the owner is dissatisfied because the adjustment is not one to which he is accustomed! The service salesman has a real problem and many new-car sales depend upon his manner of handling it.

Courteous and intelligent treatment is expected from everyone. The grease boy has as much to do with the customer's impressions as the general manager, often more. A clean shop, well-kept tools, firm but fair supervision and fair pay will bring out the best from the men, but no consistently good work can be expected from dark and greasy workrooms and the worn-out equipment.

Good mechanical work calls for proper tools and skilled hands, with proper supervision. Tools alone will not accomplish the task, nor skilled men without proper tools. The shop force must be supervised by careful and experienced men, who must train the mechanic and instill in him the spirit to turn out good work. Spirit has as much to do with an efficient shop as the skill of the men, which is useless unless backed by the right mental attitude toward the customer and the work.

For quick service, there must be ample space in which to handle cars, adequate equipment, and special tools and devices. It is astonishing how much time can sometimes be saved by a special tool or method. Too many special tools, however, easily may prove to be a hindrance. More time may be wasted in going after and making ready some special tool than might have been required to accomplish the purpose with the tools at hand. A shop equipped to do rapid repair-work necessarily will have idle equipment, because a tool which may be necessary for a certain operation may not be called for again for some time. The shop in a large city has a great advantage over a country shop because of the varieties of special work which may be performed in a moment; whereas the country shop might have to wait a long time. Quick service is dependent largely upon the simplicity and accessibility of the units in the vehicle. The service-man's burdens would be lightened greatly and the owner's satisfaction be accomplished more nearly if accessibility were given the study and importance it deserves. Nothing conduces more to quick service, proper work, dependable promises, fair prices and general satisfaction. Quick service cannot be accomplished unless the service-station has a complete line of parts for all models. The stockman's task is one of the most important in the service organization because, in addition to the necessity for a complete line of parts, there is the equal need for a sufficient turnover and economical administration to enable the department to be operated at a profit. The stock department of a main branch-station should not be considered satisfactorily efficient if less than 97 per cent of orders can be filled upon demand.

Dependable promises can be given in 90 per cent of the cases handled in an efficient service-station. There is no excuse for failure if there is a proper system of routing and following work through the various operations and departments, and the right kind of cooperation between the shop and the service office. Fair prices will depend upon the general efficiency of the shop, reasonable prices for parts and the right proportioning of overhead

expense but, in addition, prices will be influenced very largely by the accessibility of the various units in the car.

The lowest costs and fairest prices cannot be obtained with an indefinite or indifferent attitude on the part of the management. The man in the shop is human and, unless he is given a good reason for exertion, will be inclined to take things as easily as possible. A time limit must be established for each operation, and constant study must be made of ways and means to reduce it. Every item of expense and hour of labor must be accounted for if the true costs are to be known. Prices must be based on costs, and not on mere competitive price-cutting. Let fair prices to the customer be based upon efficiency in one's own shop, and not upon cutting the throat of a competitor.

Correct billing needs the attention of the service-man who hopes to collect his money promptly and in full, and at the same time eliminate the source of a very large percentage of complaints. The bill for service must be clear. The operations performed must be expressed in terms easily understood by a man of average intelligence. The materials and time should be listed clearly with the prices of each unless the prices of complete operations have been quoted in advance. The bill should be ready when the final inspection has been made. The customer should look it over at the time of delivery, when all details are clear and fresh; later they will be confused, complicated and half forgotten.

Unfair Service Demands

There is no demand of fair service that cannot be met successfully by an efficient organization. Unfortunately, all men are not easy to deal with and some are not satisfied because they expect the impossible. Some of the reasons which make satisfactory service impossible are as follows:

(1) The owner who has been oversold by the new-car salesman and comes to the service-man with demands for free work or adjustments which cannot be met; or the owner who expects his car to be something more than standard, a car designed in his own imagination as a "super" car

(2) The man who, upon entering the service-station, expects a salesman to be instantly available, no matter how busy the day, and to spend unlimited time in talking over not only business matters but unrelated subjects

(3) Complaints by the car-owner of high costs and exorbitant charges, founded not on a conception of actual costs but on intangible ideas of what the work should cost

(4) The man who thinks and acts as if a chip on his shoulder and a scowl on his face were necessary to obtain proper service

(5) The owner who expects something for nothing; who argues over the bill or complains about the work, hoping to get a reduction

(6) The very busy person who expects repairs or adjustments to be made in much less time than it is possible to do so

(7) The man who abuses his car, and blames the car for the service

(8) People who make no allowances and expect perfection in a line of business that is exceedingly liable to errors and misunderstandings. The service-man is not infallible, be he ever so skillful and conscientious

Although we have still much to learn and many improvements to make, we are endeavoring to carry out in a rather large way the things that make up satisfactory service. They include three essentials: personnel, equipment and system. I hazard the opinion that the public is becoming more motor-wise and that competition will force improvements in service as well as in production. It behooves those who would have lasting success to include in a car the features that make for accessibility, low repair-cost and quick adjustment, and to organize the service-station along business-like, uptodate lines.

THE DISCUSSION

President Bachman:—The request has been made by Past-President Manly that I outline our system of unit rebuilding. It has something to do with the so-called flat-rate billing that Mr. Page touched upon. Nothing that I may say should be interpreted as antagonistic to such a method, because I am thoroughly in sympathy with it. I think that I was one of the first, in our organization at least, to advocate such a method. However, I think that those who have had my experience with it will understand that it is not wholly satisfactory and that there are problems connected with it, the same as with everything else. As a result of work of this character, the engineering department has obtained some excellent ideas that we have been enabled to embody in later designs and to rearrange current designs in a way that make possible the handling of every vehicle by component parts and units. Mr. J. Whyte mentioned that he was pleasantly surprised to learn that a good service job is an economical production job, and I believe that this is true.

We are in the commercial-vehicle business exclusively. If a man comes in with a car that requires repairs and he needs the car promptly, we have an arrangement whereby we can interchange the unit that causes the trouble with a rebuilt unit. This unit has been put into a condition that we are prepared to guarantee will give the equivalent service of a new unit. Then we take the defective unit and repair it. We have a gang doing nothing but that sort of work; that is, we have specialists on engines, on transmissions and the like, throughout the truck. The complete carrying out of such a system is possible only at large centers; it could not be carried out completely in smaller places. We believe that this kind of service justifies a premium and we make an arrangement whereby the customer understands exactly what the cost of it to him will be. He has the privilege of accepting that or taking another form of service in the repair of his vehicle with a dependable promise as to the time of completion, so that he can arrange his business affairs accordingly.

C. M. Manly:—I hoped you would bring out something about the relative cost of new production and a complete overhauling of the units in that way. The point I have in mind is that if such data can be placed in a really accessible form and circulated, they would have great influence on the car-owner in enabling him to understand some of the real fundamentals that go to make up this question of cost of service. For instance, suppose a man knows that a rear axle costs $100 to $150. If he finds that it will really cost a very large percentage of that sum for the garage-man to take the axle down, look it over thoroughly, put in a few new parts and reassemble it, because it is a special job, and it is really an honest charge, I think it would help to remove much of the friction that Mr. Page has described as being bound to arise in connection with the question of cost of repairs, due to the lack of understanding of the public of the difference between manufacturing and overhauling.

PRESIDENT BACHMAN:—While I cannot answer that question definitely, I think I can give a relative answer. From my correspondence with our service people, I understand that they have found that the additional cost of that method generally has been considered by our customers a satisfactory and reasonable charge for the decrease in time that they are without the vehicle. Of course, that includes many factors.

W. O. HINCKLEY:—What can a service-man who is probably servicing from 20 to 30 makes of car do on that kind of proposition? If he must invest in extra axles and the like to take care of that proposition, it might mean an investment that would run up to $90,000 for overhauling various makes of car. From the service point of view, I do not know how a man could make reasonable charges and carry an overhead such as that would necessitate.

PRESIDENT BACHMAN:—I tried to cover that point on the basis that the efficient handling of such a system is dependent upon volume. If there is only a turnover of a unit once monthly, once in 2 months or something of that sort, the essential value of which runs up into a considerable amount of money, the overhead charges would increase to a point where the system gets out of line. I am dealing entirely with the handling of one make of vehicle in our own service organization. Even there we have to confine the plan largely to those territories where we have a sufficient volume to make it practicable.

WALTER E. ROBERTSON:—I have devoted much study to the subject of automobiles. It seems to me that the principal object in the design of the car has been to make it sell, and that service and economical repairs have been overlooked. With some associates, I am entering the field with an automobile part that we have been experimenting with for a long time. We might have put it upon the market a long while ago but we found a defect in our experimental work and had to scrap many of our patterns. The construction seemed to be perfect and simple at the time, yet we would find opportunities for improvement that were especially to the interest of the user. That has been the principal thing that has retarded our progress. From my observation, insufficient consideration is given to the man that ultimately will experience the troubles.

The expense of upkeep and repairs is tremendous. A man does not realize what the difficulties are in gaining access to the various parts that must be removed or repaired. The commercial side has been given more thought than has been given to the needs of the man that will use the car. The builders should think more of the man who must use the car, of its economical repair and of accessible ways of repairing it. An automobile seemingly is susceptible to getting out of order at the most inopportune time. If the builders would circulate instructions to the users in regard to how certain parts can be removed, how they can be repaired and what time is required for such repairs, it would help considerably. It seems that the trend now is to give more thought to the consumer, which is a tendency that I am glad to see coming to the front.

GEORGE S. CAWTHORNE:—A neighbor of mine overhauled his car in his own garage because the treatment he had received from the service-station had soured him. He asked me where he could buy replacement parts elsewhere than at the regular service-station. This car is very well known and very well liked so far as new cars are concerned, but it seems that the service given by those who handle it is not what it should be. That ought to be overcome very easily by courteous treatment. I think we are coming closer to that as these problems develop.

DAVID BEECROFT:—As an owner who drives his own car and pays his bills, I have to go into certain places for service. I deal with seven men previous to dealing with the man who actually does the work. That is a tremendous waste of time. I deal with metropolitan service-stations and I have often thought how much better it would be if the service representatives considered the psychology of the business man; sometimes they seem to be entirely neglectful of that consideration. The service people seem to have no realization that the time of a business man is of value, and the station is not organized to take care of its patrons properly. That is true not only of cars but of batteries and parts.

A wealthy gentleman who had been buying a certain make of car told me recently that he would not buy that make of car any more because he could not get satisfactory service. He was buying purely on the basis of service. He gave less weight to the matter of design. Whenever we make service a difficult problem we are building a barrier of sales resistance.

An official of possibly the greatest mail-order house in this Country told me recently that, in analyzing its business, the greatest asset was believed to be constituted of the innumerable acts of company service that had been performed for a period extending over a generation. Also, that the service the company had rendered, just as much as the quality of the goods, had built up the business. As an actual instance, about 17 years ago a set of dishes was bought from this company and the buyer was assured at the time that the pattern, an European one, would always be in stock. The buyer wrote recently to see if some of these dishes that had been broken could be replaced. The company replied that, due to the war, the same pattern was no longer available; but, because it had agreed that this pattern would always be in stock, it would take back the old set of dishes and give the buyer another set of standard pattern. That is service, and such service is what built up that great organization.

In a communication addressed to Herbert Hoover, Secretary of Commerce, regarding the automobile industry, the dealers of the Union of South Africa said that they insist on greater standardization. They are 6000 miles from the factories and have experienced the difficulties of carrying too much stock. They use motor vehicles for transportation. They are not luxuries. They said to the builders in America that to sell automobiles in the Union of South Africa in the quantities that the people there want them, the machines must be standardized and it must be made easier to service them and carry the parts in stock. Requests of that nature are coming in from other sections.

The automobile is a utility vehicle. Whenever we ponder that there are a certain number of people in the Country with salaries sufficient to enable them to own a car of a certain quality, we are looking entirely away from the real market. The sale of automobiles cannot be gaged on the basis of the salaries of the people of the world. In 1885 my father kept two road horses on our farm. We had about 20 horses, but these 2 horses did nothing but take us to church or to market and do miscellaneous road work. Those horses were never used to plow or harrow or do similar work. My brother lives on the same farm today and for years has had his automobile and his motor truck. They are just as essential and constitute the same economic portion of his home as did

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The Measurement of the Property of Oiliness[1]

By Robert E. Wilson[2] and Daniel P. Barnard, 4th[3]

Annual Meeting Paper *Illustrated with* Photographs and Charts

THE term "oiliness" is defined as that property of lubricants by virtue of which one fluid gives lower coefficients of friction (generally at slow speeds or high loads) than another fluid of the same viscosity. Its importance under practical operating conditions is shown to be greater than is generally recognized. Unfortunately, however, no satisfactory method has ever been developed for the quantitative measurement of this property in comparing different lubricants.

The paper describes the variety of possible methods of measuring the property of oiliness and of throwing light on the mechanism of partial lubrication, including (*a*) the use of a Deeley-type machine to measure coefficients of friction between plane surfaces at slow speds; (*b*) a refined and reproducible method of determining static coefficients of friction between partially lubricated metal surfaces; (*c*) the measurement of the interfacial energy between oil and mercury; (*d*) measurements of the electrical resistance and the rate of formation of adsorbed films on metal surfaces; and (*e*) the clogging of fine metal capillaries through which lubricants are forced. Some other interesting preliminary experiments also are described.

In the light of the results obtained by the abovementioned methods, it is believed that the static-friction test, with proper refinements, is the best single measure of the properties of oiliness, but that it should be supplemented by measurements of the thickness of the adsorbed films at high pressures, in order to throw more light on the mechanism of the action of different constituents in lubricating oils.

Animal and vegetable oils are almost invariably superior in oiliness to straight mineral-oils. The blending of considerable proportions of these neutral glycerides with mineral oils greatly improves their oiliness, but the same results may be accomplished by adding much smaller proportions of other materials, such as fatty acids or oil-soluble soaps.

These experiments confirm entirely the customary hypothesis that oiliness is due to selective adsorption of constituents in the oil by the metal surface, but the common conception of a mono-molecular adsorbed film that acts merely by masking the attractive forces of the metal surfaces for one another appears to be incorrect. The adsorbed film is shown to be of colloidal rather than molecular dimensions, is a plastic solid rather than a fluid-film, and apparently acts by smoothing over surface irregularities, carrying much of the load, and minimizing metal-to-metal contact and abrasion. The structure and physical characteristics of this film seem to be more important than its thickness in determining its efficiency in lowering friction.

The constituents of lubricants that form these adsorbed layers can be selectively adsorbed and largely removed from the oil by repeated treatments with very finely divided metals, such as iron-by-hydrogen.

IN their previous article the writers have shown that under certain adverse conditions—especially at slow speeds and high loads or where the oil supply is inadequate—a perfect fluid lubricating film cannot be maintained, and lubrication of the rubbing surfaces depends on the ability of a very thin, probably semi-solid, film of lubricant to adhere to the metal surfaces in spite of the pressure tending to squeeze it out and the abrading effect due to motion. This fundamental property of "oiliness," which is possessed in variable degrees by all good lubricants, has been the subject of a considerable amount of investigation, chiefly in England; but, although there is considerable evidence to indicate the presence of some such adsorbed film, its composition, structure, thickness, and the mechanism of its formation, are matters which still remain to be established. Furthermore, no simple and satisfactory *quantitative measure* of the property of oiliness has yet been devised.

For the purposes under discussion, the "oiliness" of a lubricant will be defined as the property by virtue of which one fluid gives lower coefficients of friction (generally at slow speeds or high loads) than another fluid of the same viscosity.

One reason why the property of oiliness has not received the attention it appears to deserve lies in the fact discussed in the previous paper; namely, that practically all well-designed journal bearings operate for at least 95 per cent of the time under conditions of perfect fluid-film lubrication, where the oiliness of the lubricant plays no part. As a result, many are inclined to question the practical value of a detailed consideration of the more exceptional and complicated case of *partial* lubrication, where the speed is too low or the load too high to maintain the normal fluid-film between the metal surfaces, and the property of oiliness becomes important. Since this point of view is frequently taken by experienced lubrication engineers, it seems desirable to point out the following basic reasons why the laws of partial lubrication and the property of oiliness are of very real practical importance, apart from their theoretical interest.

(1) Every bearing must occasionally start and stop, and thus pass through the region of partial lubrication, where the friction coefficients are enormously higher than at normal speeds and some abrasion is certain to result. The resultant roughening of the bearing surfaces is directly or indirectly responsible for a large proportion of bearing failures, although the actual failure may take place only after the bearing has been running for some time at high speeds, when the rough surface causes overheating. By using a lubricant of high oiliness that will maintain a film even when the bearing is not rotating, it is possible to minimize this abrasion and its resultant effects

[1] This is the second part of the paper on The Mechanism of Lubrication, by the same authors, that was presented at the 1922 Annual Meeting of the Society. The first part was printed in the July, 1922, issue of The Journal, p. 49.

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(2) Conditions very frequently occur, especially in machinery in the hands of unskilled operators (under which head we may include most automobiles) where the oil supply is temporarily deficient for one reason or another. Under these conditions the only salvation of the bearing is a tenaciously adsorbed film of lubricant which will remain for a long time and prevent seizing and damage to the bearing, even though it gives a higher coefficient than that of the fluid-film which should be present

(3) In many cases, such as the piston-rings in an engine cylinder or the crosshead of the steam engine, there is a reciprocating motion between flat surfaces and the maintenance of a perfect fluid-film under these conditions, especially at the ends of the stroke, is very difficult, and the amount of friction depends very largely on the permanence and lubricating value of the adsorbed film. The precise type of lubrication in the cylinders is, to be sure, not so important in many of the more poorly made engines where, to quote a well-known contemporary, "the threads on the piston-rings do not fit those in the cylinder"

(4) There are many special uses of lubricants where high pressures and comparatively slow speeds are absolutely essential, under which conditions only a strongly adsorbed film can prevent seizing of the surfaces. Important examples under this head are the lubrication of gears, where greases are usually employed to maintain a lubricating film, and in cutting or threading most metals, where lard oil is unquestionably superior to ordinary mineral oils

(5) From the standpoint of the producer of lubricants, a study of the film-forming tendency of oils appears to be indispensable, since this unmeasured oiliness factor is the only fundamental difference between good lubricants, poor lubricants and so-called non-lubricants of similar viscosity. Under these circumstances, it is surprising that neither the producers nor the consumers of oils have developed any recognized test or specification to tell the difference between the amount of oiliness possessed by different lubricants, even though such tests might hamper the remarkable imagination and fluency of the average oil salesman when discussing this phase of the subject

(6) Probably the most important way in which the property of oiliness affects the power losses in practically all bearings, even when operating under conditions of perfect fluid-film lubrication, apparently has never been pointed out. This is the influence that the property of oiliness has on bearing design

As has been shown in the previous paper, bearings are designed primarily to operate in the range of perfect fluid-film lubrication and reasonably near to the point of minimum friction. Unfortunately, it is not possible to operate exactly at this point because it is just on the verge of the dangerous condition of partial lubrication. It is therefore necessary to multiply the value of $z\,N/p$ at the critical point by a factor of safety of, say, 5 to determine the safe operating value, though these conditions give much higher coefficients of friction than the minimum value.

The effect of the oiliness of the lubricant on this matter of design is apparently two-fold; first, it lowers to a considerable extent the critical point[4]; and, second, it decreases the danger attendant upon operating occasionally in the region of partial lubrication. It is therefore quite reasonable to use a smaller factor of safety if a lubricant with a high degree of oiliness is assured. In other words, a bearing supplied with a very oily lubricant could be designed to operate at a value of $z\,N/p$ determined by multiplying a *lower critical value* by a *lower factor of safety*, thus giving a *much* lower operating coefficient of friction than if reliance could not be placed on the degree of oiliness possessed by the lubricant.

In view of the foregoing facts, the research laboratory of applied chemistry at the Massachusetts Institute of Technology believes that the whole question of oiliness and the mechanism of lubrication at low speeds is the most important present problem in the entire field of lubrication, from both a practical and a theoretical standpoint. As the first point of attack upon the problem, the laboratory has been endeavoring for some time to work out satisfactory methods of measuring this oiliness factor, and has also been conducting experiments designed to throw light on the mechanism by which the film is formed.

In this preliminary investigation of the factor of oiliness we offer no apology for the fact that we have not as yet attempted to simulate actual working conditions in bearings and the like. As has already been pointed out, the factors which determine the coefficient of friction in a bearing are many and are separable only with difficulty. Theoretically, under certain conditions a bearing could be used to measure the *viscosity* of a lubricant; practically, the only way to obtain a satisfactory degree of accuracy is to use a viscosimeter that bears no resemblance to a bearing; similarly, in developing the quantitative measure of *oiliness* it is desirable to go to extreme conditions and eliminate all other factors as far as possible. It is also our belief that undue reliance should not be placed on any single supposed test of the oiliness factor in the present preliminary stage of the work, but that several radically different methods of measurement should be tried to determine which results are most uniformly consistent with the known properties of the oil and its behavior in actual service tests in bearings operating under conditions of partial lubrication. This comparison of the results obtained by different methods of testing should also aid greatly in explaining the mechanism of partial lubrication.

Thus far we have made use of six independent methods of measuring some property connected with the adsorbed lubricating film on metal surfaces, not to mention several others that have been tried out and discarded for various reasons. The results of these preliminary studies are admittedly inconclusive in many important details, but a number of new and interesting facts have been brought to light and it is hoped that a detailed presentation of the methods used may stimulate discussion and research in this important field.

In view of the specified definition of oiliness in terms of the coefficients of friction for partially lubricated surfaces, measurements of the coefficient of friction under conditions which emphasize the effect of oiliness are the obvious first approach to a solution of the problem. This means that the measurements should be made in the region of partial lubrication, by using either very low speeds or high pressures.

In undertaking such a study, it is well to recognize at the outset one very serious and apparently inescapable difficulty that besets any method of measuring friction under conditions of partial lubrication. This difficulty is due to the combination of two facts: first, in this region the nature and condition of the surfaces profoundly influence the coefficient of friction; and, second,

[4] As indicated in the preceding paper, insufficient work has been done to settle this point definitely.

some abrasion is certain to result if the test is severe enough to distinguish clearly between good and bad lubricants. It is therefore necessary to use extreme care in the preparation of the surfaces if reproducible results are to be secured, and the surfaces must be refinished and brought back to their original condition after virtually every test. As a result, the time spent in lapping and repolishing surfaces is generally a matter of days, as compared with minutes required for making the actual friction measurements. This results in slow progress, especially in the early stages of a fundamental investigation where the relative importance of the various factors and the proper methods for obtaining the best results are not yet established. This difficulty is even more pronounced in working with journal bearings, because any repolishing or scraping tends to increase the clearance and change the whole behavior of the bearing. The use of flat bearing surfaces for such tests is therefore decidedly advantageous.

Results on a Deeley-Type Friction-Machine

The most promising method described in the literature for studying the mechanism of partial lubrication at slow speeds and comparatively high loads is the Deeley type of machine.[5] Apparently only one of these machines has been constructed previously, that by Mr. Deeley himself,

[5] The Deeley-type machine and its use are described in some detail in the 1920 Report of the Lubricants and Lubrication Inquiry Committee of the British Department of Scientific and Industrial Research.

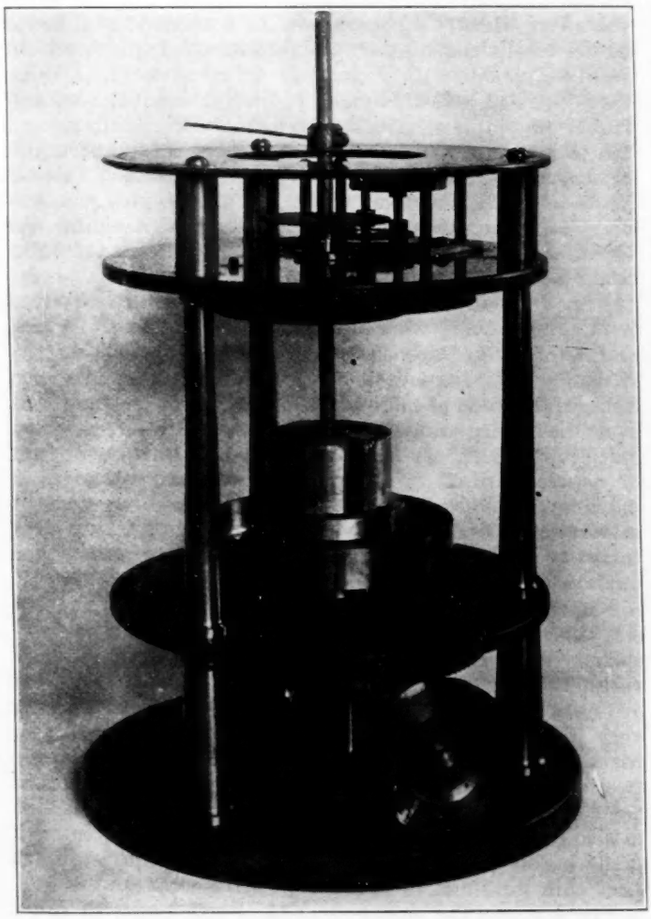

Fig. 1—Deeley-Type Friction-Machine Used in Studying the Mechanism of Partial Lubrication at Slow Speeds and Comparatively Heavy Loads

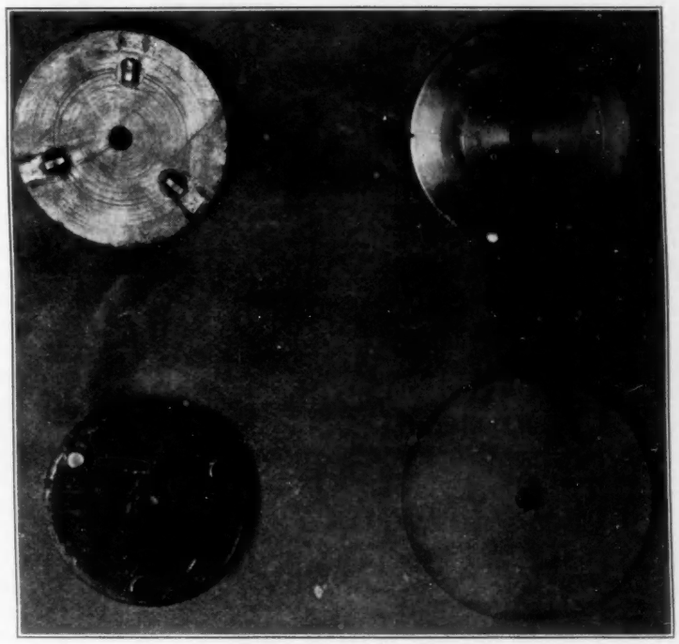

Fig. 2—The Two Essential Elements of the Deeley-Type Friction-Machine, a Flat Plate and the Disc, Which Is Supported by Three Pegs, That Rests Upon It

and the meager amount of data secured was insufficient to permit the formulation of important conclusions.

The construction of the Deeley-type machine used by this laboratory is shown in Figs. 1 and 2. It consists essentially of a flat plate that can be rotated at any desired (slow) speed, on which rests a disc supported by three pegs and pressed down by weights of any desired size. The disc is held in place by a small vertical shaft that is free to turn except for the restraint imposed by a calibrated spiral spring. When the bottom plate is rotated at constant speed, the top disc follows it until the spring overcomes the frictional resistance and slipping begins. The first maximum reading on the graduated scale measures the static coefficient of friction, and the steady position that it assumes as rotation is continued is a measure of the kinetic coefficient at the speed in question. A damping device is added to prevent too violent oscillations of the system when the disc first breaks away.

The general procedure in making measurements is as follows: When glass surfaces are used they are first cleaned by washing with soap and water and then with chromic acid. They are next rinsed thoroughly with distilled water and dried on a clean cotton towel. They are then placed on the machine, the receiver filled with oil, covering the bottom plate to a depth of 1/16 in., and the machine run at high speed and light load for several minutes to rid the surfaces of any adhering moisture film. In making a series of readings the machine is adjusted to the speed required, the load is applied, and as soon as the pointer comes to rest the reading is noted and the machine stopped. In this way undue abrasion is prevented, as the pointer almost always comes to rest after one or two revolutions of the turntable. By the time that a half a dozen readings can be taken, however, the surfaces are so badly scored that it is necessary to refinish them before they can be used again. This rapid wear affects the results considerably, but thus far no way has been found of avoiding it. For this reason the values given below must be considered only approximate.

In using metal surfaces the procedure followed is some-

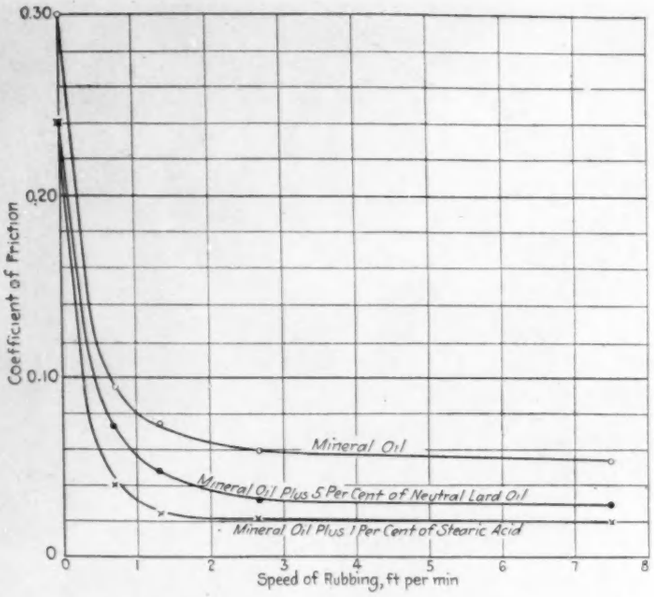

FIG. 3—RESULTS OBTAINED WITH GLASS RUBBING SURFACES AT A PRESSURE OF 300 LB. PER SQ. IN.

what different. The plate used consists of a case-hardened tool-steel disc which, after hardening, is ground true and polished. The tripod is made of cast-iron and has rectangular feet, approximately 1/16 x 1/4 in. They are placed so that the longer dimension is at right angles to the path of travel. These surfaces are ground together first with carborundum flour and then run dry for several days until both surfaces are bright and smooth. They are next oiled and run-in for about 50 hr. more. Following this treatment the surfaces are removed from the machine, carefully cleaned and oiled with the oil to be tested, and the machine run till constant readings are obtained. This is frequently a period of from 8 to 10 hr.

One of the principal questions that it was hoped to settle by using the Deeley machine was whether the coefficient of friction drops off steadily with increasing speed, or whether it first rises from the static value and passes through a maximum at very slow speeds. A statement to the latter effect is made by Archbutt and Deeley[6] and repeated by several other recent writers on the subject, but the experimental data on which it is based seem to be extremely meager[7] and, in view of the difficulty of obtaining reliable results under conditions of partial lubrication, it was felt desirable to check up this statement which seems contrary to both theory and general experience. It was also felt that a study of the static coefficient and the kinetic coefficient at slow speeds would throw considerable light on the best conditions under which to obtain a quantitative measure of the property of oiliness.

Using the above-described machine, an extensive series of observations has been made to determine primarily the effect of varying speed on the coefficient of friction under conditions of partial lubrication. Typical sets of results are shown in Figs. 3 to 6 inclusive. In making these tests an effort is made to distinguish between animal or vegetable oils, most of which are known to possess the property of oiliness in a high degree, and straight-refined mineral-oils of similar viscosity, of which Velocite B, made by the Vacuum Oil Co., is fairly typical. It was also desired to check up the observations of Archbutt and Deeley on the effect of adding small amounts of fatty acids to the mineral oil.

Fig. 3 shows some of the results that were obtained with this machine when using rubbing surfaces of glass, and brings out clearly the effect on the coefficient of friction of adding small amounts of fatty constituents to a light, high-grade paraffin-base spindle-oil. It it noted that over the entire range of rubbing speeds covered, from static up to 8 ft. per min., the oils containing 5 per cent of neutral lard-oil and 1 per cent of stearic acid gave much lower values for the coefficient than did the straight mineral-oil. Stearic acid to the amount of 1 per cent serves to lower the coefficient even more than does 5 per cent of the neutral animal-oil.

The values shown for the static coefficient are undoubtedly inaccurate, due to the great tendency of the well-cleaned glass surfaces to seize and give widely variable results. Glass also does not appear to adsorb a film from ordinary lubricants at all firmly, and hence it gives a very high static coefficient. The glass surfaces used in these tests all showed very deep scratches after one or two readings had been obtained. The very rapid drop in the coefficients as soon as appreciable speeds are reached is also consistent with what might be expected from such plane highly polished surfaces that would require only a very thin fluid-film to prevent all solid contact.

Fig. 4 shows the variation of the coefficient with speed of rubbing for a given oil, rapeseed, at two different temperatures. It is interesting to note that at low speeds the higher temperature gives the higher coefficient, while

[6] See Lubrication and Lubricants, by L. Archbutt and R. M. Deeley, p. 60. Kimball found such a case in some "decidedly anomalous" results on steel against steel surfaces.

[7] See A New Investigation of One of the Laws of Friction, by A. S. Kimball, *American Journal of Science and Arts*, vol. 13, p. 353; also, Journal Friction at Low Speeds, by A. S. Kimball, vol. 15, p. 192

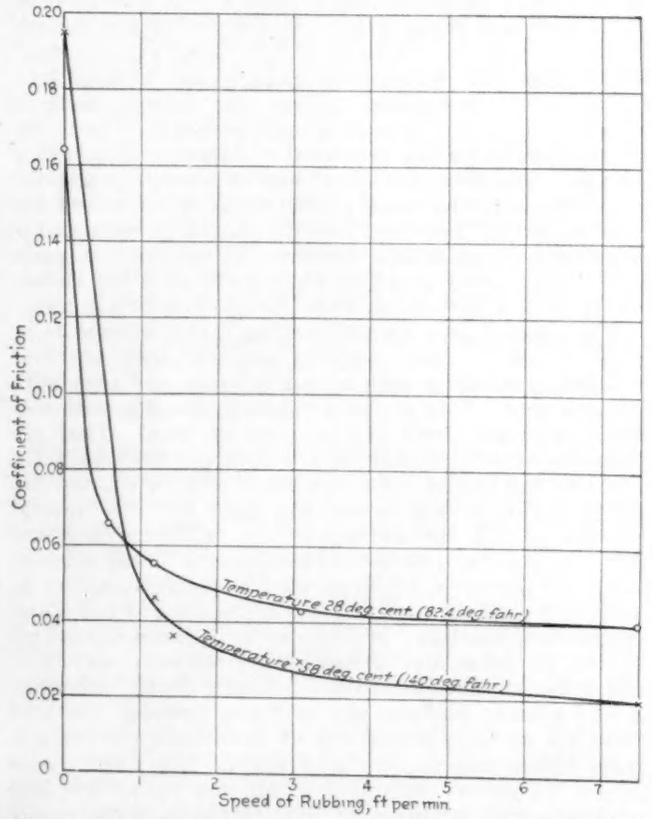

FIG. 4—VARIATION OF THE COEFFICIENT OF FRICTION WITH CHANGES IN THE SPEED OF RUBBING
In This Test Blown Rapeseed-Oil Was Employed with Glass Rubbing Surfaces That Were Subjected to a Pressure of 300 Lb. per Sq. In.

at speeds above 1 ft. per min. the two curves reverse their relative positions. This is readily explainable on the basis of the fact that adsorption is the main factor in reducing the coefficient at lower speeds, and this is always more pronounced at lower temperatures; whereas, at higher speeds, the viscosity of the fluid is the primary factor in determining the friction, and this is lower at the higher temperature.

In Fig. 5 the effect of adding small amounts of stearic acid to the mineral oil is shown, using cast-iron against steel surfaces. The presence of but 0.5 per cent of the fatty acid apparently lowers the coefficient to less than one-half of its former value in the range studied. Increasing the fatty-acid content to 2 per cent effects a further, though less marked, reduction. The relatively enormous effect of such small additions apparently can be explained only on the assumption that the fatty acid is *concentrated* in a surface film by a selective adsorptive force at the metal surface. The curves again show a steady decrease from static friction with increasing speed of rubbing, the drop being, however, much less precipitous than for glass surfaces.

Fig. 6 compares the results on blown rapeseed-oil, mineral oil, and mineral oil plus 2 per cent of oleic acid. The oleic acid appears slightly superior to the stearic acid as an adulterant after motion has started, though the static coefficient is somewhat higher. The straight blown rapeseed gives only slightly lower values than the mineral oil plus oleic acid.

It is impossible within the scope of the paper to present all of the rather extensive experimental results secured on this machine. For example, several series of tests were made to determine the effect of load on the coefficient of friction at speeds up to 80 ft. per min., and with pressures varying from 25 to 140 lb. per sq. in. The curves for different loads were practically identical in shape and fairly close to one another in position. The relative positions of the curves for different loads were not always consistent, but in general the lower loads tended to give slightly lower coefficients at moderate speeds, though most of the differences were not much greater than the experimental error of duplicate runs. Additional measurements were made of the *static* coefficient at loads up to 1600 lb. per sq. in. without noting any consistent variations, though the average deviation of duplicate measurements at the higher loads was about 15 per cent.

As a result of the work on the Deeley-type machine, the following conclusions can be drawn as to the friction between *plane surfaces* at *slow speeds:*

(1) There is no maximum coefficient of friction at very slow speeds, the static coefficient always being higher than any kinetic coefficient

(2) For polished glass surfaces, the drop from the static coefficient to the slow-speed kinetic is extremely sharp and it is doubtful if the curves should really be considered as continuous. On metal surfaces, however, the static coefficients are not so high and are more reproducible, and the curves appear to be continuous, the static coefficient being only slightly higher than those at very slow speeds

(3) Within wide limits pressure has comparatively little effect on the *coefficient* of friction under the above-specified conditions

(4) Animal and vegetable oils show consistently lower coefficients than ordinary refined mineral-oils

(5) The addition of very small amounts of fatty acids, or of considerably larger amounts of neutral vegetable-oils, to mineral oils, produces a very marked lowering of the coefficient of friction, thus confirming the statements of Southcombe and Wells

(6) On metal surfaces the maximum differences in the coefficients of friction for different oils are found in the neighborhood of zero velocity. In other words, the *static* coefficient of friction appears to be the best single measure of the oil-

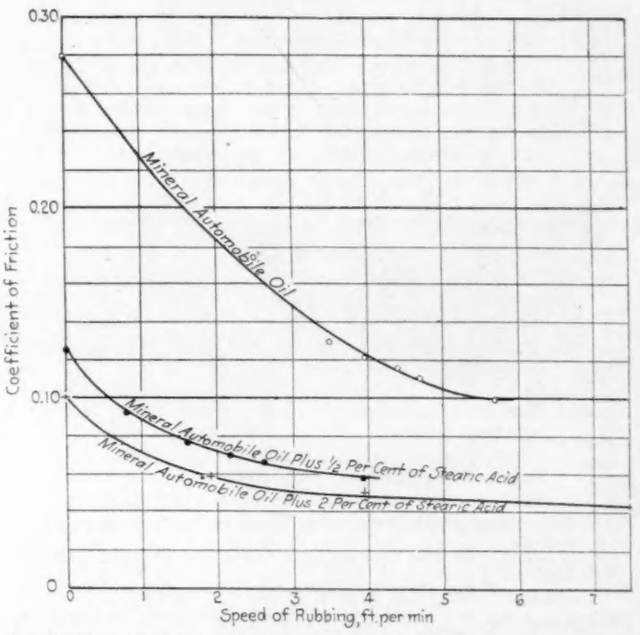
0.30
0.20
0.10
0
Coefficient of Friction
Mineral Automobile Oil
Mineral Automobile Oil Plus ½ Per Cent of Stearic Acid
Mineral Automobile Oil Plus 2 Per Cent of Stearic Acid
0 1 2 3 4 5 6 7
Speed of Rubbing, ft. per min

FIG. 5—EFFECT ON THE KINETIC COEFFICIENT OF FRICTION OF ADDING SMALL QUANTITIES OF STEARIC ACID TO A MINERAL LUBRICATING OIL
The Surfaces in Contact Were Cast Iron and Steel and the Pressure Was 30 Lb. per Sq. In.

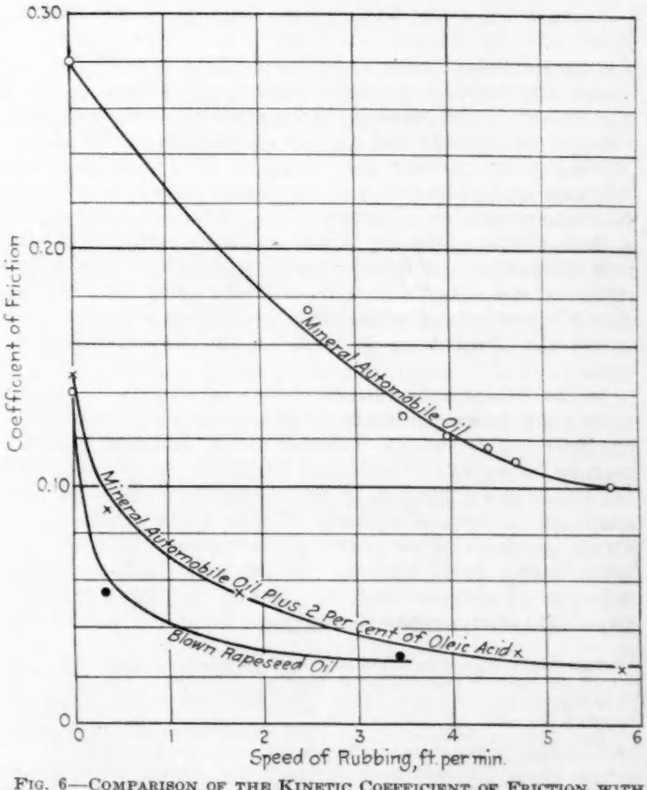

FIG. 6—COMPARISON OF THE KINETIC COEFFICIENT OF FRICTION WITH BLOWN RAPESEED-OIL AND MINERAL OIL WITH AND WITHOUT OLEIC ACID
The Surfaces in Contact Were Cast Iron and Steel and the Pressure Was 30 Lb. per Sq. In.

iness factor of a lubricant, especially considering the greater simplicity of the measurements. Slightly greater *percentage* differences, and greater reproducibility, may be obtained at speeds in the neighborhood of 0.5 ft. per min., but such conditions would require more complicated apparatus and cause much more abrasion than would the determination of the static coefficient

(7) All of the above data confirm the belief that the oiliness factor of lubricants is due to a tenaciously adsorbed film of some constituent of the lubricant, the presence of which diminishes or prevents metal-to-metal contact, even after the surfaces have been pressed together for some time. This ability of the film to withstand prolonged pressure without being squeezed out indicates that it partakes of the nature of a plastic solid[8] with a fairly high yield-point, rather than being a fluid-film such as does the lubricating in a rapidly rotating bearing. To account for its remarkable effectiveness, even on surfaces with very appreciable irregularities, this film would apparently have to be much thicker than the mere mono-molecular film which is frequently postulated

Measurement of the Static-Friction Coefficient

In view of the fact pointed out in conclusion (6) just preceding, and of the time-consuming nature of measurements on the Deeley machine, it seemed highly advisable to develop a rapid and reproducible method of measuring the *static* coefficient of friction for a large number of oils, reserving the use of the Deeley-type machine for making a more thorough study of the more promising possibilities as indicated by these static-friction measurements. A considerable amount of the time therefore has been devoted to the development of such a test, which has proved more difficult than was anticipated, although a fairly satisfactory solution has now apparently been attained.

Some interesting work along these lines has already been done by Langmuir[9], Hardy[10], and Lord Rayleigh[11]. Langmuir made measurements of the angle of slip between non-metallic crystal surfaces, such as mica, quartz and galena, in the presence and absence of mono-molecular films of fatty acids and similar substances, while Hardy worked with various pure organic liquids on polished bismuth and glass surfaces and again obtained evidence of mono-molecular adsorbed films. Lord Rayleigh made a few observations on glass surfaces. None of the sets of results is, however, readily applicable to the lubrication of metal surfaces with ordinary lubricants, though Hardy's methods of measuring the static coefficient were essentially those used in most of our measurements to date.

In the initial experiments in this laboratory, attempts were made to determine the static coefficient between flat surfaces. The results obtained were entirely unsatisfactory owing to the practical impossibility of reproducing the original flatness of the surfaces and the size and shape of the area of contact. It was found necessary to obtain surfaces of as nearly perfect *smoothness* as possible, rather than working toward true flatness. True flats can be obtained only by lapping methods, and consequently always show many tiny scratches which are far more objectionable from the standpoint of accurate friction measurements than very appreciable variations from precise flatness.

It might be argued that excessive smoothness would give results widely different from those obtained with the ordinary types of surface that are used in engineering practice, and such a possibility is indeed quite conceivable. As indicated previously, however, the primary need is for definite reproducible measurements of the oiliness property; reproducible measurements require reproducible surfaces; if surfaces of a definite intermediate smoothness could be thus reproduced they might prove entirely suitable for the purpose in hand, but no procedure to attain this end has yet been suggested, and the only alternative is to make the surfaces so extremely smooth that further changes in degree of smoothness would not affect the results. Furthermore, preliminary measurements with surfaces of intermediate degrees of roughness have shown that the order of magnitude and arrangement of results is nearly the same for all reasonable degrees of smoothness, but that the average deviation of the observations becomes less and less as the surfaces become smoother.

To avoid these serious difficulties, a modified method was developed which consists essentially in the measurement of the static coefficient (from the angle of slip) between two surfaces, one of which is a highly polished and approximately plane surface, while the other is a highly polished spherical segment with a definite radius of curvature, 6 in. By this expedient it is possible to focus all attention on the smoothness of the surface, while minor variations in the planeness or curvature of the surfaces have but little effect. Furthermore, the pressure per unit area is high without requiring the use of large weights, and is reproducible, although its exact magnitude is unknown. Fortunately, however, ten-fold variations in the load, 20 to 200 grams (0.705 to 7.055 oz,) have not been found to affect the results more than 3 or 4 per cent on the average.

To the uninitiated it may seem a fairly simple matter to produce surfaces that have a mirror-like smoothness and yet possess the other necessary properties. The most obvious method at first sight would be to electroplate the surfaces with some metal, such as gold, silver, or copper, that readily takes a high polish, but experiments with such surfaces indicate that even with comparatively small loads the surfaces are so soft that they are actually "plowed" up whenever static-friction measurements are made, and it was felt that the measurements were more a function of the internal properties of the soft metal film than of the adsorbed oil film. Other experiments with soft and readily burnishable metals lead to the conclusion that fairly hard materials must be used to obtain accurate and reproducible results.

One material that takes a remarkably good polish, and yet possesses a high degree of hardness, is speculum metal, a definite crystalline compound of copper and tin in the proportions of 68.2 per cent of copper and 31.8 per cent of tin. This metal is very brittle, but with proper care can be cast into the form of discs, hemispheres or pegs which take an excellent polish. The metal also has the advantage of being practically non-corrodible.

In view of the probable specificity of different metals in building up an adsorbed film, it seemed desirable to approximate most service conditions by making at least one of the surfaces out of steel, preferably fairly hard. Considerable difficulty was experienced in securing suitable pieces of steel that were free from microscopic inclu-

[8] This belief was enunciated and some supporting data offered by one of the authors at the Rochester, N. Y., meeting of the American Chemical Society, in April, 1921. See *Chemical and Metallurgical Engineering*, May 11, 1921, p. 825.

[9] See Surface Phenomena of Ore Flotation, by I. Langmuir. *Transactions of the Faraday Society*, vol. 15, part 3, p. 62.

[10] See Static Friction, part 2, by W. B. Hardy. *Philosophical Magazine*, Series 6, vol. 38, p. 32; also vol. 40, p. 201.

[11] See Notes on the Theory of Lubrication, by Lord Rayleigh. *Philosophical Magazine*, vol. 35, p. 157.

sions of oxide or pits. Furthermore, many steels can be ground to a very smooth surface and yet in the long polishing operation by cloth tend to develop irregularities due to differences in the hardness of different parts of the grain structure, or to form pits due to corrosion. To get a steel reasonably free from non-uniformities, recourse was had to the stock used in making micrometer checks, etc., or to the best quality of case-hardened tool-steel with very fine grain. The second difficulty (corrosion) has been overcome by using kerosene instead of water as the liquid on the polishing wheel. The surfaces are prepared by lapping to the desired form, rough-polishing with 60-min. carborundum on a canvas-covered wheel, and finishing with levigated alumina on a wheel covered with a fine grade of broadcloth.

Static-friction measurements have been made with various combinations of these two metals and also with alloy No. 5, a low-melting alloy (containing bismuth, tin and cadmium) which it was found possible to cast in smooth hemispherical form on watch glasses, but was too soft to give entirely satisfactory results. The best combination appears to be to make the spherical segment out of speculum metal and the plane surfaces of annealed high-carbon steel, both being polished to a mirror-like smoothness. With such a combination of surfaces most of the abrasion comes on the steel, and 25 or 30 observations can be made before repolishing by moving the slider each time to a fresh part of the steel surface.

In measuring the static coefficient the plane surface is placed on a support, the angle of inclination of which can be slowly raised by a motor acting through a belt, light gears and a cord and pulley to prevent the transmission of vibrations. The plane is flooded with oil, the curved slider placed in position on the plane and the angle of inclination slowly increased until slip occurs. A stop is provided to prevent the slider from slipping more than about $\frac{1}{8}$ in. The surfaces with tripod slider recently adopted are shown in position for a determination in Fig. 7.

Table 1 shows the results of the preliminary experiments on four different combinations of surfaces with several typical oils that might be expected to differ in the property of oiliness. Each of the recorded results is an average of not less than 10 and generally about 20 separate observations of the static friction coefficient. The average deviations varied from 2 to 5 per cent, being generally below 4 per cent, so that the probable error of the average of 20 observations is generally less than 1 per cent so far as a particular set of surfaces is concerned. It has been found, however, that even in the case of the best combination thus far found (speculum against speculum), differences in the degree of polishing make perceptible differences in the results, even when a high degree of smoothness is apparently approached. Speculum against steel gives slightly greater deviations, but is recommended in order to approach more closely to service conditions. Therefore, too much reliance must not be placed on the precise reproducibility of the different observations before further work shall have been done.

As to the significance of the typical results given in Table 1, it will be noted in the first place that there is again a sharp distinction between lubricants, such as lard oil, which are known to possess a high degree of oiliness, and ordinary mineral oils; and also that small

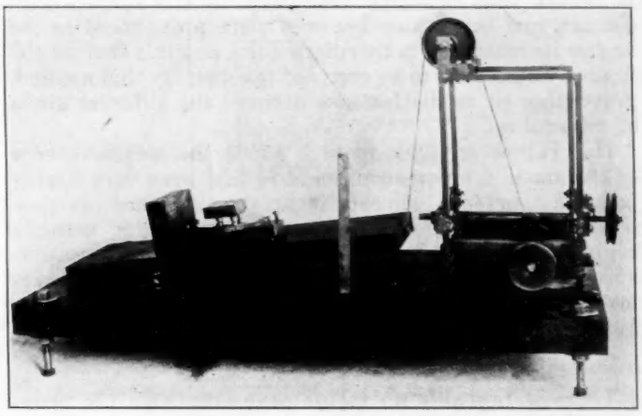

FIG. 7—ARRANGEMENT USED TO MEASURE THE STATIC COEFFICIENT OF FRICTION ON AN INCLINED PLANE SURFACE EMPLOYING A TRIPOD SLIDER

amounts of stearic acid added to mineral oils, such as Velocite B, give values that correspond very closely to the animal or vegetable oils. These results all check up remarkably well with the previously discussed results on the Deeley-type machine, except as to the precise magnitude of the static coefficients. It will be noted that ferric stearate also is very effective in lowering the coefficient, though the soap is rather unstable on standing in the mineral oil.

To show that not all constituents which lower the surface tension between oil and water necessarily lower the static friction coefficient, results are given on Velocite B oil containing 2 per cent of para-cresol. This raises, rather than lowers, the coefficient of friction and indicates that the mere presence of an adsorbed film is not the only essential point, but that its structure is also important. This point is discussed more fully in the following section.

One difficulty with the above method of measurement with the spherical segment on a plane surface is the impossibility of determining the dry coefficient of friction, because in the absence of any liquid the segment begins to twist about on the vertical axis through its point of contact, and slowly works its way down the surface at comparatively low angles of inclination. This can be overcome by using a viscous non-lubricant, such as glycerin, which, as will be noted, gives the highest coefficients observed for these surfaces. It should be said, however, that the higher observed values for the static coefficient of friction are open to some question, since the spherical segment tends to roll slightly[12] as the plane

TABLE 1 — STATIC-FRICTION MEASUREMENTS BY THE INCLINED-PLANE METHOD USING A SPHERICAL SEGMENT SLIDER WITH A LOAD OF 100 GRAMS (3.527 OZ.)

	Coefficient of Friction		
Oil	Speculum on Steel	Speculum on Speculum	Alloy No. 5 on Steel
Glycerin	0.200	0.200	....
Velocite B	0.182	0.173	0.152
Velocite B, plus 2 per cent of Stearic Acid	0.125	0.121	0.123
Velocite B, plus 0.5 per cent of Iron Stearate	0.120	0.120	....
Neutral Lard,	0.125	0.126	0.093
Velocite B, plus 2 percent of Para-Cresol	0.184	0.178	....
Velocite B Treated with Iron-by-Hydrogen	0.190	0.180	....

[12] Since this paper was presented these difficulties have apparently been overcome by using a slider consisting of a heavy metal disc supported on a tripod of three speculum pegs, each $\frac{1}{4}$ in. in diameter and polished off to a $\frac{1}{2}$-in. radius of curvature. This arrangement gives considerably higher coefficients for dry friction, glycerin, and the like, but insufficient work has been done to establish a series of definite values on the new arrangement.

is raised, thus bringing new parts of the surface into contact, and this action becomes more pronounced as the angles increase. It is therefore quite possible that all the higher values tend to be crowded together by this method, preventing sharp distinctions between the different kinds of mineral oil.

One rather striking feature about the measurements of the static friction coefficients is that even very highly polished surfaces almost invariably produce surface scratches of an appreciable depth when sliding actually begins, although it appears that these scratches are produced only after the slider begins to move, and therefore play no part in determining the value of the starting coefficient.

Significance of Surface-Tension Measurements

There is probably no factor connected with the property of oiliness that is so frequently mentioned without any clear notion of its true significance, as surface tension. For example, it seems to be assumed generally that a lowering of interfacial surface-tension between the oil and the metal must in some way *necessarily* lower the coefficient of friction, whereas there is no such necessary relationship. Even Southcombe and Wells in their extensive studies along these lines are open to serious criticism as regards their method of presentation.

When any two immiscible liquids are in contact, the molecules in the surface layers are in a partially unbalanced condition and possess a certain amount of potential energy, due to the fact that the molecules of the one liquid do not attract those of the other as much as they attract like molecules. If this were not true, the molecules of one liquid would dissolve indefinitely in the other liquid, as is the case with *miscible* liquids, and there would be no interfacial surface.

It therefore requires work to bring enough molecules of each liquid from the interior of their phases to form the interfacial layers, and the amount of energy thus required per square centimeter of interface formed is called the interfacial surface energy in ergs per square centimeter (which is precisely equal numerically to the more frequently used, but less clearly visualized term, surface tension, in dynes per centimeter).

The magnitude of this interfacial surface energy, as we shall now refer to it, is readily measureable by a variety of means, the most common of which is the determination of the drop weights of one liquid when slowly dropped into another from a capillary of known diameter. In this case the force of gravity is caused to work against the forces tending to prevent the increase of surface and the drop falls when the force of gravity just exceeds the opposing forces, the magnitude of which can then be readily calculated.[13]

If molecules of some third substance are also present in one or both of the immiscible liquids, other interesting possibilities arise. Consider, for example, an interface between oil and water, with some soap present. Soap consists of a long hydrocarbon chain with an active group containing oxygen and some metal at one end. The long hydrocarbon chain is soluble in oil, but the active end with the metal atom is not. Therefore, comparatively little soap will dissolve in the oil layer. On the other hand, the active end has a marked affinity for, and is quite soluble in, water, but the hydrocarbon chain prevents much of it dissolving (except in the form of a colloidal solution where the hydrocarbon chains probably form the interior of colloidal particles with the outside largely made up of the active groups).

It is obvious from these considerations that the one place where a soap molecule can be most "comfortable" is in the interface, with the hydrocarbon chain in the oil layer and the active water-soluble group in the water layer; and we would expect to find a very much higher concentration of soap at the interface than in either of the separate phases, which has actually been proved to be the case. Furthermore, the presence of this type of molecules which are, so to speak, *anxious* to concentrate in the interface, makes it easier to produce more interface. In other words, it lowers the interfacial surface energy more or less in proportion to this concentrating tendency. For substances in the molecular state, the precise relation between the lowering of surface energy and the increase in concentration has been worked out on thermodynamic grounds by Willard Gibbs, but his fundamental equation does not apply quantitatively to the concentration of *colloidal* particles at the interface, though it is frequently and erroneously so used. For the purpose in hand, therefore, a lowering of the interfacial energy is simply a measure of the tendency of certain constituents to become concentrated at an interface, and, by measuring the amount of such lowering, the extent of such concentration can be determined roughly.

In an exactly similar way, there is an interfacial energy between any liquid and any solid, and the tendency of any molecules to concentrate at this interface will cause a lowering of this interfacial surface energy. Unfortunately, however, in spite of many references to this quantity as though it were definitely measureable, no method has ever been developed for

[13] See *Journal of the American Chemical Society*, vol. 42, p. 2534, for a detailed discussion by Harkins of these measurements and calculations.

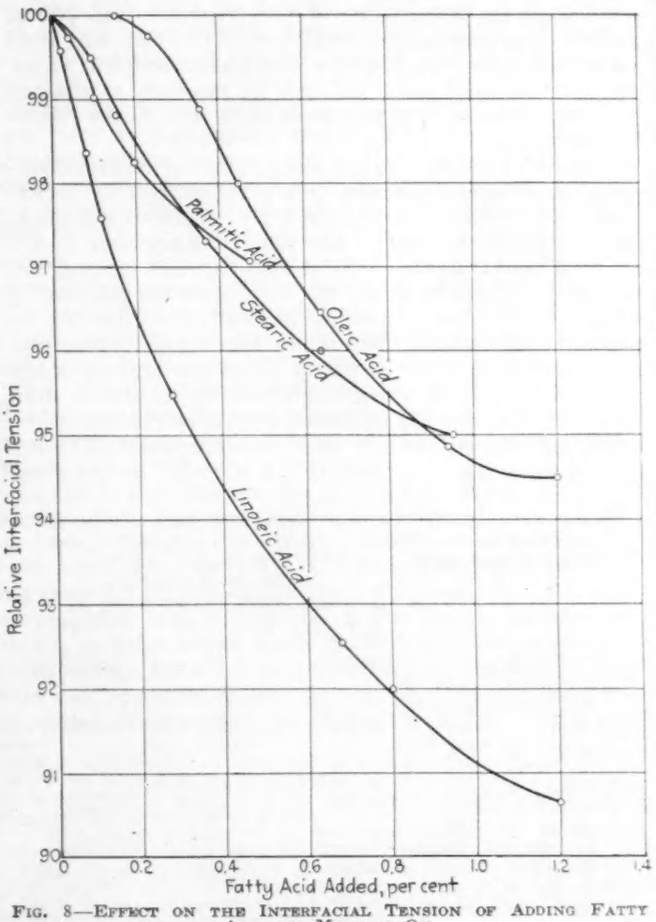

Fig. 8—Effect on the Interfacial Tension of Adding Fatty Acids to Mineral Oil

measuring the interfacial surface-tension between a solid and a liquid.[14] On account of this difficulty many have assumed erroneously that anything which lowered the surface tension between any two liquids would also lower the surface tension between one of those liquids and any metal. This is probably true in a very general and qualitative sense, but the two effects are by no means sufficiently parallel for the assumption to be of real value in making comparisons between different constituents of an oil, because it is obvious that the tendency of molecules to concentrate at a metal surface depends upon the attraction between these molecules and those of the metal, which would certainly be greatly different from their attraction for water molecules. In spite of this fact, the writings and patent claims of Southcombe and Wells indicate their belief that anything which lowers the surface tension between an oil and *water* will decrease the coefficient of friction between partially lubricated metal surfaces.

It does seem conceivable, however, that the lowering of interfacial energy between oil and metal surfaces could be determined approximately by making measurements between oil and mercury, the only pure metal that is liquid at ordinary temperatures. At any rate, the approximation would be much better than that obtainable by using water as the second liquid. This laboratory had just completed the construction of an apparatus for such determinations when the interesting results of Bhatnagar and Garner[15] were published, and accordingly only a few preliminary measurements have thus far been made.

[14] It should be said that there are some bare possibilities of arriving at an approximate measure by very special means that never yet have been carried to the limit.

[15] See *Transactions of the Society of Chemical Industry* (London), vol. 39, p. 185T.

[16] See Temperature Coefficients of Surface Energies of Liquids, by F. M. Jaeger, *Verslag. Akademie van Wetenschappen*, vol. 23, p. 330.

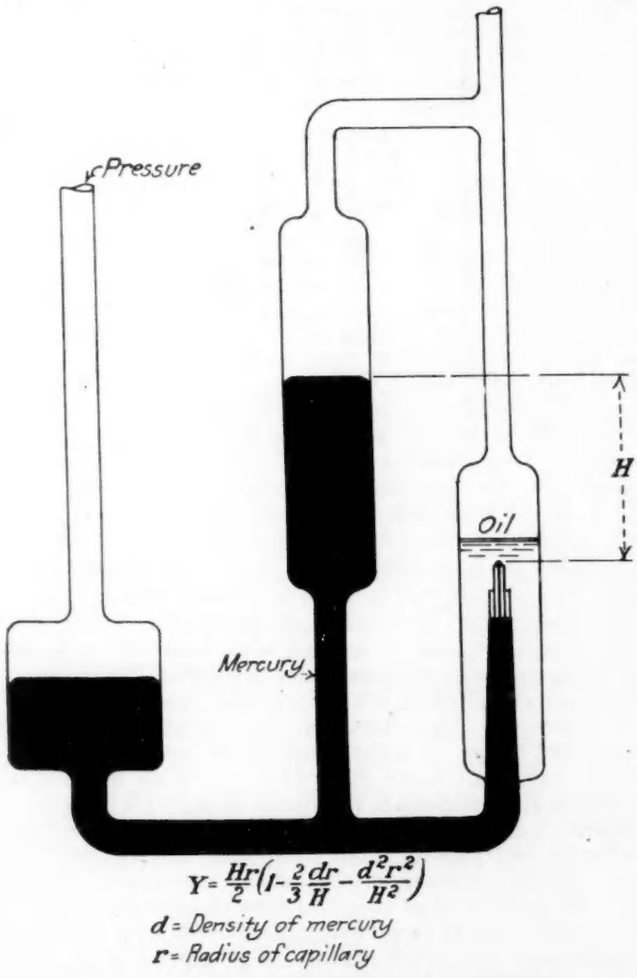

FIG. 9—APPARATUS EMPLOYED TO DETERMINE THE INTERFACIAL TENSION

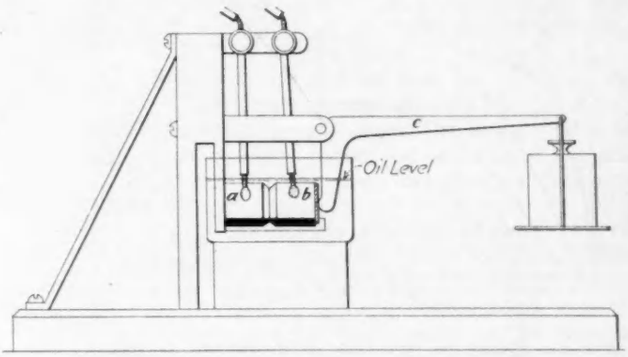

FIG. 10—"CONDUCTIVITY" APPARATUS USED FOR DETERMINING THE ELECTRICAL RESISTANCE OF ADSORBED OIL FILMS

Bhatnagar and Garner's results with four different fatty acids dissolved in mineral oil are shown in Fig. 8. It will be noted that each has its characteristic curve, though linoleic acid seems to be more highly adsorbed than the other three. Palmitic and stearic acids give almost identical results, as would be expected from their chemical similarity.

The method developed by this laboratory is somewhat simpler, being based on the method of Jaeger.[16] The essential portion of the apparatus is shown in Fig. 9. The interfacial tension between the mercury and the oil is measured by the head of mercury, *H*, necessary to cause the drops to separate from the capillary which is immersed in the oil. The method is much more rapid than, though probably not quite as accurate as, that of Bhatnagar and Garner.

Even granting, however, that the results against mercury surfaces will parallel roughly those against other metals, it must be emphasized that these results do not have any direct bearing on the coefficient of friction between partially lubricated surfaces, in spite of frequent assumptions to the contrary. *Lowering of interfacial energy is only a measure of the tendency of some constituent to concentrate at the metal surface;* whether or not this results in a lowering in the friction coefficient *depends almost wholly on the nature and structure of this adsorbed film.*

This fact is brought out rather strikingly by some of the static-friction measurements just discussed, in which the effects of 2-per cent additions of para-cresol and of stearic acid to mineral oil are compared; both lower the surface tension against mercury; both therefore are concentrated at the metal surface; but while the stearic-acid film greatly lowers the coefficient, the para-cresol film appears to give even slightly *higher* coefficients than the plain oil.

On the basis of these and some other preliminary results, plus certain theoretical considerations, we believe that a partial lubricating film, to be effective in reducing friction coefficients between metal surfaces under high pressures, must possess the properties of a *solid* rather than of a *fluid*-film, and must be of *colloidal* rather than of ordinary *molecular* dimensions. Para-cresol apparently fails in one or both of these specifications, while stearic

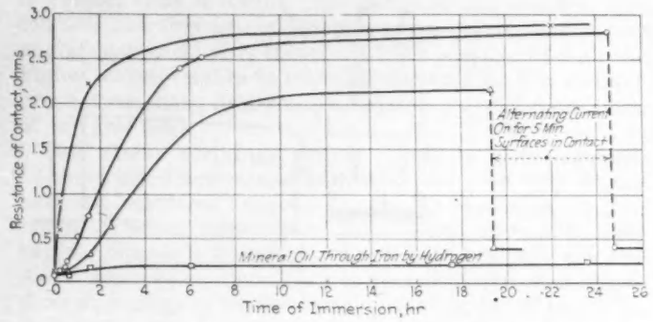
Resistance of Contact, ohms
Time of Immersion, hr
Alternating Current On for 5 Min Surfaces in Contact
Mineral Oil Through Iron by Hydrogen

FIG. 11—EFFECT OF THE TIME OF IMMERSION ON THE CONTACT RESISTANCE OF MINERAL OIL

acid possesses them in a high degree, as is demonstrated by some later experiments.

ELECTRICAL-RESISTANCE MEASUREMENTS OF ADSORBED FILMS

As pointed out previously, interfacial-energy and static-friction measurements show the indisputable presence of adsorbed films on metallic surfaces in contact with lubricants. They do not, however, give any definite information as to the thickness or physical characteristics of that film. The writers have therefore conducted some experiments designed to give some idea of the rate of formation and the thickness of the adsorbed film by means of its electrical resistance, with results that were far more striking than could have been anticipated. The procedure employed is outlined briefly as follows:

A "conductivity apparatus" was constructed, as shown in Fig 10. The oil-film under examination is held between the two hardened-steel surfaces, *A* and *B*. The contact faces of these surfaces (originally ½-in. micrometer checks) are lapped and polished true until they adhere tightly when dried and lightly pressed together. The resistance of the contact between these two surfaces was measured by a Wheatstone bridge arranged so that balance could be obtained by either a battery supplying direct current and a galvanometer or an alternating-current microphone hummer and phones. The tests were carried out in the following manner:

The surfaces were carefully polished and cleared, placed in the apparatus as indicated, and a definite moderate pressure applied through the lever *c* and the "dry" resistance noted. This was very low, usually about 0.03 ohm when all traces of air had been removed from the surfaces by gentle rubbing under pressure. Part of even this was undoubtedly due to the leads and connections. The load was then removed, the surfaces separated, immersed in the oil under examination and again placed under pressure. Some little time (about 15 min.) was required for the contact resistance to drop off to a substantially constant value. Usually the first value thus obtained was two or three times the "dry" resistance. The surfaces were again separated, immersed in the oil for a longer period of time and then placed together, and the resistance again noted. This time the observed values were very much higher. This procedure was followed at intervals for about 24 hr., at the end of which time there was in general very little tendency toward increasing resistance. The results of a number of experi-

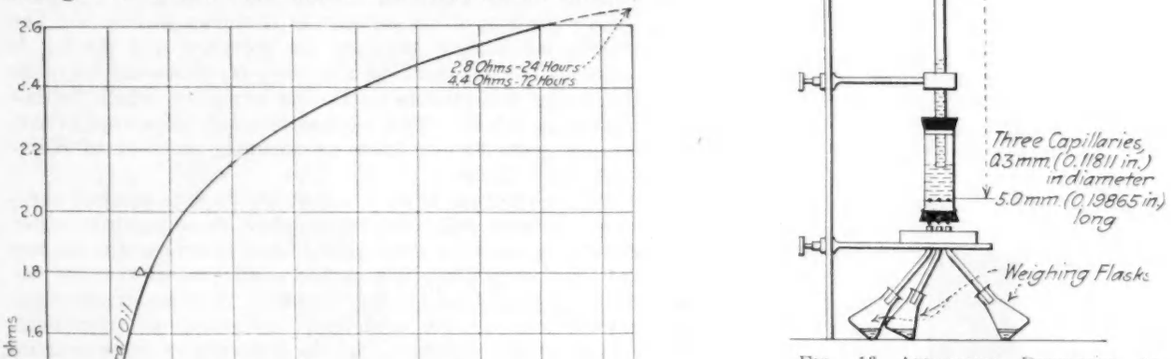
2.8 Ohms - 24 Hours
4.4 Ohms - 72 Hours
Mineral Oil
Land Oil
Mineral Oil Plus 2 Per Cent of Stearic Acid
Mineral Oil Through Iron by Hydrogen
Contact Resistance, ohms
Time of Immersion, hr

FIG. 12—EFFECT OF THE TIME OF IMMERSION ON THE CONTACT RESISTANCE WITH VARIOUS LUBRICATING OILS

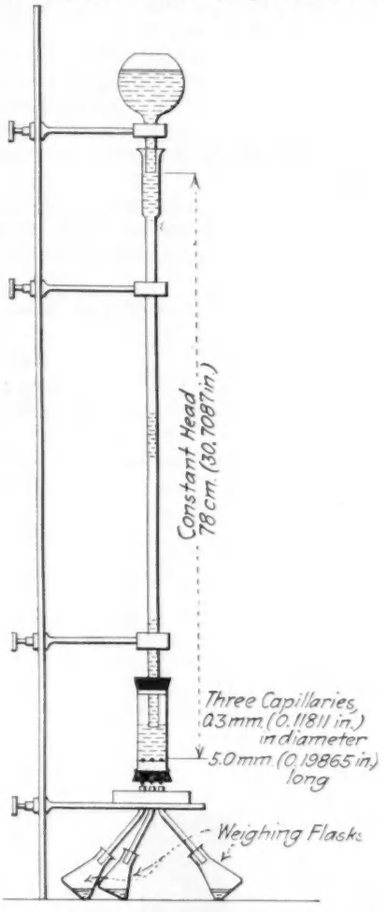

FIG. 13—APPARATUS DEVELOPED TO STUDY THE CLOGGING OF CAPILLARY TUBES

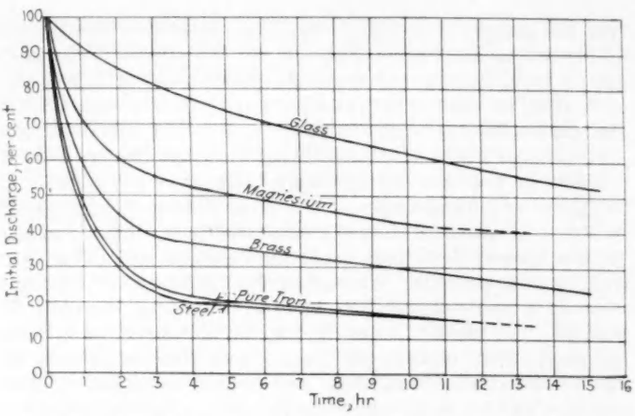

FIG. 14—FILM FORMED BY UNTREATED VELOCITE B ON VARIOUS CAPILLARY TUBES

ments are shown in Figs. 11 and 12. It is evident that the film increases fairly steadily in thickness for about 6 hr., after which the curve tends to flatten off. The different curves in Fig. 11 are for the same mineral oil, Velocite B, and were obtained by regrinding and polishing the surfaces for each series of observations. The divergence indicates the lack of reproducibility, at least in these preliminary experiments. Part of the trouble is due to the difficulty of separating the surfaces after they have been in contact for some time without scraping off part of the film. This is especially true of the more tenuous portion formed after the first hour or two, which is so sensitive to rough handling that it probably plays no important part under service conditions. The first 10 or 20 per cent is much more tenaciously held, although even then vigorous rubbing or wiping will remove all but a comparatively small proportion of the total film thickness. Experiments are now being made with much higher pressures to permit distinction between lightly and firmly adsorbed films.

One phenomenon accompanying these experiments that we have thus far been unable to explain satisfactorily, is the evident destruction of the film when subjected to an alternating electromotive force, even though the voltage and current be extremely low. As indicated in Fig. 11, after the film had attained a resistance value of from 2 to 3 ohms, measured by means of the battery and galvanometer, the circuit was changed so as to impress on the film an alternating electromotive force of very low voltage, but of approximately 1000 cycles per sec. on the film, in an effort to check the measurements by the microphone hummer. Although the current thus passed was less than 1 per cent of the amount used in the direct-current measurements, the resistance fell off with great rapidity to the low value of about 0.4 ohm. Some more recent experiments have shown that a *heavy* direct current has much the same effect, probably due in this case to heating. Since the observations do not vary appreciably, regardless of the length of time the ordinary direct current of 0.002 amp. is applied, the effects of the very small alternating current cannot be due to straight electrolysis, though they might be attributed to the action of rapidly alternating electrical stresses on a gel-like adsorbed film.

One of the most interesting features of these experiments is the surprisingly long time required for the film to build-up in the case of the straight mineral-oils. The most reasonable explanation of this observation appears to be that the film-forming constituents of the mineral oil are present in comparatively small proportion, and that considerable time is required for them to diffuse to the metal surface. To test this out, the same oil was shaken up for several hours with two successive portions (20 per cent by weight each) of very finely divided iron (made by reducing ferric oxide with hydrogen). The iron

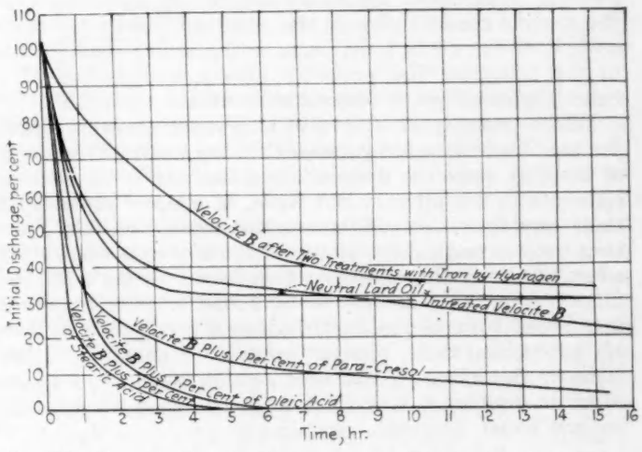
Initial Discharge, per cent
Time, hr
Velocite B after Two Treatments with Iron by Hydrogen
Neutral Lard Oil
Untreated Velocite B
Velocite B Plus 1 Per Cent of Para-Cresol
Velocite B Plus 1 Per Cent of Oleic Acid
Velocite B Plus 1 Per Cent of Stearic Acid

FIG. 16—FLOW OF VARIOUS OILS THROUGH A BRASS CAPILLARY TUBE

was then separated by centrifuging and the resistance measurements repeated, with the results shown in Fig. 12. It will be noted that the resistance rises to only 8 per cent of its former value. This might, of course, be due to a decrease in the specific resistance of the film, rather than to a decrease in its thickness, but careful tests did not disclose any iron soaps or suspended iron in the treated oil. It would therefore appear that a considerable proportion of the film-forming constituents had been removed by selective adsorption on the large amount of iron surface offered by the iron by-hydrogen. It is hoped also that by extraction of the adsorbed mate-

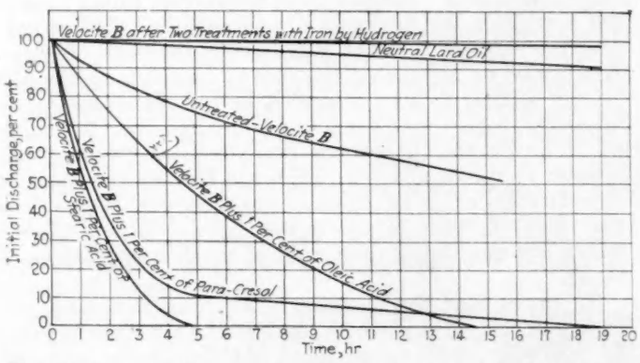
Initial Discharge, per cent
Time, hr
Velocite B after Two Treatments with Iron by Hydrogen
Neutral Lard Oil
Untreated Velocite B
Velocite B Plus 1 Per Cent of Oleic Acid
Velocite B Plus 1 Per Cent of Para-Cresol
Velocite B Plus 1 Per Cent of Stearic Acid

FIG. 15—FLOW OF VARIOUS OILS THROUGH A GLASS CAPILLARY TUBE

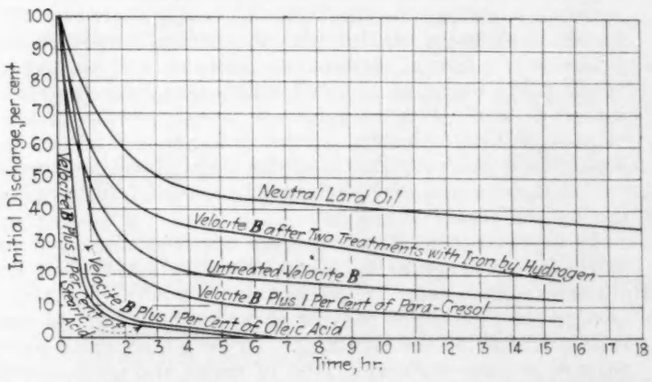
Initial Discharge, per cent
Time, hr
Neutral Lard Oil
Velocite B after Two Treatments with Iron by Hydrogen
Untreated Velocite B
Velocite B Plus 1 Per Cent of Para-Cresol
Velocite B Plus 1 Per Cent of Oleic Acid
Velocite B Plus 1 Per Cent of Stearic Acid

FIG. 17—FLOW OF VARIOUS OILS THROUGH A STEEL CAPILLARY TUBE

rial plus the oil held in the pores and between the particles of the iron, followed by further concentration by readsorption on a smaller amount of surface, it may be possible to isolate and identify the "essence of oiliness" (?) thus separated. It will be noted that the oil thus treated showed an increase in its static coefficient of friction (See Table 1).

Fig. 12 shows the results of similar experiments with lard oil and with Velocite B plus 2 per cent of stearic acid, compared with the results on plain Velocite B plotted on a smaller scale.

It will be noted that the first two (which from other experiments appear to possess the greater oiliness) reach their maximum resistance much more quickly than the mineral oil, although its magnitude is much less. It is obvious, however, that the resistance cannot be taken as a direct measurement of the thickness of the film because of wide variations in the specific resistance of the different oil-films, which is, for example, probably much greater for the mineral oil than for the other two. Neither is it possible to calculate the film thickness by assuming that the specific conductivity of the adsorbed film is the same as that of the oil in bulk, because the active constituents in the adsorbed film probably have conductivities of a much higher order of magnitude than the oil in bulk.

Efforts were made to arrive at a more accurate figure for the film thickness by measuring the electrical capacity of the film, since the dielectric constants of different constituents in the oil vary but little, in marked contrast to their conductivities. This was not found feasible, however, on account of the previously mentioned disrupting effect of alternating electromotive forces on the adsorbed films. Apparatus is now being constructed with which it is hoped to measure the thickness directly by a system of mechanical and optical levers. Meanwhile, other methods described in the next section were tried in an effort to determine how thick such adsorbed films might become under favorable conditions.

Clogging of Metal Capillaries

In view of the above-mentioned uncertainties as to the thickness of the adsorbed films, it was thought that a study of the rate of clogging of very fine metal capillaries when an oil with film-forming tendencies was run through them, might throw some light on this subject. Experiments were first made with capillaries approximating in dimensions those in the standard Saybolt viscosimeter, maintaining a small constant head at all times. These results showed that the rate of flow through glass and metal capillaries tended to decrease gradually over a period of hours, even though the temperature was accurately controlled. The change was, however, less than 5 per cent and it was difficult to control the temperature accurately enough to distinguish sharply between different thicknesses of film. It did confirm, however, the presence of a film of appreciable thickness and seemed to account for many of the difficulties that have been observed in attempting to get check measurements on lubricants of high viscosity in the ordinary viscosimeters. As a check, glass capillaries of the same dimensions were run in parallel and they showed only a negligible clogging during the period of the run.

To magnify the effect, recourse was therefore had to much smaller capillaries, about 0.3 mm. (0.118 in.) in diameter and 5 mm. (0.197 in.) long, where the thickness of the film might become an appreciable part of the total diameter of the capillary. To get an accurate comparison between different types of metal and glass, three jets of almost identical dimensions were used in parallel on the same oil in all tests, the apparatus being constructed as shown in Fig. 13, on which all dimensions are given. Using such small capillaries, it was found that the results were quite erratic until the oil was filtered through 200-mesh wire-gauze to remove all dust and foreign particles, of a size likely to affect the results.

Most of the comparisons were made between capillaries of glass, steel and brass of the same dimensions, through which the same oil flowed simultaneously. Observations of the rate of flow were made by weighing the efflux during 10-min. periods. The efflux during successive periods showed a marked decrease, as is indicated by Figs. 14, 15 and 16. To make the results comparable in spite of variations in the viscosity of the oil, and the precise size of the capillaries, all the data are plotted in terms of percentage of the weight flowing in the first 10-min. period, before appreciable clogging had time to take place, and this initial flow was always very nearly the same for all three capillaries.

Inspection of the three charts indicates, first, that the rate of clogging of the glass capillary was in all cases very much less than that of the metal capillaries, indicating a less tenacious adsorption or a thinner adsorbed film. The only cases in which the decrease even approached that of the metal capillaries was where various organic acids were added to the mineral oil. The results with the glass capillary do, however, show that the very rapid changes in flow are not due to any change in the viscosity of the oil as a whole. This is also shown by the fact that the results obtained after thoroughly cleaning the capillaries always gave results that checked with the original rate of flow.

Proceeding, then, to the consideration of the results with brass and steel, which more nearly measure the specific oiliness property in which we are interested, it will be noted that, under the conditions of these tests, all the oils build up a film of surprising thickness, of the order of magnitude of 0.1 mm. (0.004 in.). It also indicates that the thickness of the film is greater for Velocite B than for neutral lard-oil, and this fact, coupled with the static friction data, indicates that the thickness of the film, at least under comparatively low shearing-stresses, is by no means the only factor of importance in determining the "oiliness" of a lubricant. On the other hand, the effects of addition agents such as stearic acid, oleic acid and para-cresol, which other tests have shown to be adsorbed at the metal surface, are uniformly found to increase the rate of formation and thickness of the film, and in the cases of the oleic and stearic acids to stop the flow entirely after about 6 hr.

The results on the Velocite B treated with iron-by-hydrogen confirm the previous conclusion that this treatment removes a considerable proportion of the film-forming constituents. Similar treatments with Fuller's earth did not affect the thickness of the adsorbed films except possibly making a slight decrease in the case of glass. It will also be noted that the rate of building up the film is very similar to that indicated by the resistance measurements, being rapid for a few hours and then flattening off. The film thicknesses are, however, undoubtedly much greater in the capillary experiments than in the flat disc experiments, or in lubricating practice, due to the very low rates of shear in the former case. Similar experiments are now being conducted at much higher rates of shear.

To prove that the clogging effect was due primarily to a selective adsorption by materials that were present in relatively small proportions, the capillaries were allowed to soak in Velocite B, although the oil was not

passed through the capillaries. Upon measuring the flow after a 6-hr. soaking it was found to be 92 per cent of the normal initial flow, indicating that clogging under these conditions was inappreciable compared with the amount that took place when a large amount of oil was brought into contact with the metal surface.

To determine whether this method would confirm some unpublished results of Dr. A. E. Becker of the Standard Oil Co. which showed cast iron to be greatly superior to wrought iron or magnesium in its film-forming properties, capillaries were constructed of pure Armco iron and of metallic magnesium. The results on Velocite B with all five of the capillaries tested are shown in Fig. 17. The iron and steel check very closely, while the magnesium corresponds more nearly to glass, possibly due to the presence of an oxide film that partially saturates the normal free field of force of the metal.

From a practical standpoint, these experiments indicate the desirability of making viscosimeter capillaries from a comparatively inert material, such as glass, quartz, or agate, rather than from metal, which apparently has a considerably greater tendency to clog with ordinary lubricating oils.

Miscellaneous Experiments

Adsorption of Stearic Acid by Iron-By-Hydrogen:—To throw further light on the action of the iron-by-hydrogen in removing some film-forming constituents from oil, and to demonstrate that the fatty acids were adsorbed at metal surfaces, quantitative experiments have been made on the adsorption of stearic acid from oils by very active pyrophoric iron. The iron powder was made by reducing ferric hydroxide gel with hydrogen at 450 deg. cent. (842 deg. fahr.), the process requiring 2 weeks to give complete reduction at this temperature. The experimental procedure consisted of treating a solution of stearic acid in Acto, a rather fluid, colorless paraffin oil, with several successive portions of pyrophoric iron, allowing the solution to stand, with intermittent shaking for about 24 hr., whizzing out the suspended iron particles, and analyzing the residual oil for stearic acid. The results of some of these experiments are given in Tables 2 and 3.

Some experiments were also made in which incompletely reduced pyrophoric iron, or pyrophoric ferrous oxide, was used in lieu of the pyrophoric iron. The oxide appears to possess a much stronger affinity (probably chemical) for the fatty acid than the completely reduced metal, as is shown in Table 4.

Although careful tests were made, in no case was there any evidence of the presence of appreciable amounts of iron stearate in the solution, although it may have been formed and immediately adsorbed.

Increase in Apparent Volume of Finely Divided Iron:—A few tests were made to determine whether the presence of the adsorbed film would increase the apparent volume of finely divided iron after centrifuging a definite weight for a definite time. The iron used in this case was very finely divided, but not pyrophoric. The apparent volume of duplicate weighed samples centrifuged from benzene checked within about 1 per cent. Other samples of equal weight, shaken with oils and centrifuged 25 min. (much more than necessary to give substantially constant volume), gave *increases* in apparent volume as shown in Table 5.

Cutting Tests:—A few tests were made to determine the effect of varying degrees of oiliness on the behavior of cutting lubricants. A piece of mild steel was given a deep rough-cut with a Stellite tool, taking due precautions to keep the oil as the only variable. There was a marked difference in the smoothness of the resulting cuts, the lard oil being the smoothest, Velocite B plus 1 per cent of stearic acid a close second, plain Velocite B much rougher, and Velocite B heated with sulphur worst of any. Even more striking results have recently been obtained by Bingham and others at the Bureau of Standards.

While these tests were a satisfactory confirmation of the previous conclusions as to oiliness, there seemed to be no way to make the comparisons quantitative, and further work was accordingly discontinued.

Methods Approximating Service Conditions:—There are three very promising methods of investigating the effect of oiliness in a manner approaching service conditions, two of which were mentioned in the previous paper. They are:

(1) Investigation of the effect of oiliness on the critical value of zN/p in a normal full bearing. This laboratory is now undertaking such tests, using a Sperry gyro-compass and applying high loads by processing the gyro

(2) Investigation of the length of time bearings will continue to operate with a moderate coefficient of friction after the oil feed has been discontinued. Viscosity is also a variable affecting these results, but practically can be eliminated in a series of comparative tests between oils of similar viscosity but varying composition

(3) Investigation of the power losses in gears under heavy loads and lubricated by oils. Some inter-

TABLE 2—ADSORPTION OF STEARIC ACID

Stearic acid originally present, per cent	0.600
Stearic acid left after treating 50 grams of solution with 10 grams of pyrophoric iron, per cent	0.280
Stearic acid removed per gram of iron, grams	0.016

TABLE 3—ADSORPTION OF STEARIC ACID

Original concentration of stearic acid in oil, per cent	1.220
Concentration left after treating 100 grams of solution with 20 grams of pyrophoric iron, per cent	0.840
Concentration left after treatment of residual oil (90 cc.) with a second 20-gram portion of iron, per cent	0.600
Weight of stearic acid removed by first treatment per gram of pyrophoric iron, grams	0.019
Weight of stearic acid removed by second treatment per gram of pyrophoric iron, grams	0.011

TABLE 4—ADSORPTION OF STEARIC ACID

Stearic acid originally present, per cent	0.530
Stearic acid left after treating 50 grams of solution with 10 grams of pyrophoric ferrous oxide, per cent	0.040
Stearic acid removed per gram of iron oxide, grams	0.025

TABLE 5—INCREASE IN APPARENT VOLUME OF FINELY DIVIDED IRON

Shaken With	Increase in Apparent Volume, per cent	Duration of Contact, hr.
Velocite B	8	5
Velocite B	14	24
Acto	8	24
Acto, plus 2 per cent of Stearic Acid	8+	24

esting results have been obtained by this method[17] in England,[18] which confirm the superiority of vegetable and animal over mineral oils under these conditions of partial lubrication

The general conclusions that have been drawn from this work are covered adequately in the abstract at the beginning of the paper. In closing, we desire to acknowledge the courtesy of the General Motors Research Corporation and of the Standard Oil Co. of New Jersey in permitting the publication of these results; and the invaluable assistance of Harry Myers and Tyler Fuwa of this laboratory, who have made all the static-friction measurements and capillary-clogging measurements respectively.

THE DISCUSSION

CHAIRMAN H. C. MOUGEY:—I notice that stearic and oleic acids, lard oil and iron stearate were used. The iron stearate, according to the data presented, seemed to be very good. Has Professor Wilson any opinion as to the relative value of adding acids, glycerids and soaps to oil?

PROF. R. E. WILSON:—We realize that most of the things we are now trying are out of the realm of possibility for practical use but believe that if we study enough of them, we shall find something possessing the desirable properties and none of the undesirable ones. The glycerids must be used in larger amounts; they are not adsorbed so readily as the fatty acids and we know exactly why that is. The glycerids are much less corrosive and it may be something of the glycerid type that will afford the ultimate solution. I have in mind something like an ester with a small molecule on one end and a large molecule on the other. Here we would get away from the corrosive tendency of a fatty acid, which is certainly undesirable, yet have something that is adsorbed much as a fatty acid would be. I believe it is not necessary to have a half-way compromise between something that will gum up, or oxidize readily, and something that will lower the static-friction coefficient. I think we can dodge that dilemma because we know from other considerations that unsaturated compounds are not so highly adsorbed as certain oxygen-containing compounds.

J. E. POGUE:—How about the addition of solids to the lubricants?

PROFESSOR WILSON:—That is one of the very important things on our list, but we have not reached it yet. We know when we bring a third-solid phase into the system, we shall introduce other troubles; so we want to be sure of our ground on two solids. However, the addition of solids such as graphite may very likely be found helpful.

T. E. COLEMAN:—Could any of the fatty or organic acids be made so that they would be unemulsifiable in the crankcase?

PROFESSOR WILSON:—That is related very closely to one point that I mentioned. The reason that some of these additional agents form emulsions with water in the crankcase is that they lower the surface tension between the water and the oil. It is entirely conceivable that we could get something that would lower the surface tension between the metal and the oil without doing the same between the water and the oil but in general anything that does one thing will have some tendency to do the other; so probably we shall always have to watch for that difficulty.

R. W. A. BREWER:—Can you say anything about the effect of camphor?

PROFESSOR WILSON:—No.

G. W. COGGESHALL:—Did you try different metals in that last test where you measured the electrical resistance of different types of oil? Would the same thing occur on platinum, for example, which would not react chemically?

PROFESSOR WILSON:—Not yet. Mr. Barnard informs me that he did try to use brass on one of the oils containing fatty acids but he got corrosion and was not able to make the measurements. In regard to whether the same thing would happen with platinum bearings, there is no doubt that some of the materials used did react chemically with the metal surfaces. Adsorption is, however, the *first* thing that takes place. The chemical reaction is slower. We get our best results as the coefficient of friction on a material like brass within an hour or so after the oil is added. Later if we see any etching of the surface, very frequently we get poorer results that we can trace directly to the fact that the surface is rougher. We are evidently dealing primarily with a physical adsorption which is determined by the chemical structure of the molecules of the lubricant.

C. M. MANLY:—Have any experiments been made to indicate what effect the porosity of cast-iron has in producing the "magic" quality that seems to be obtained by straining oil through cast-iron filings? Cast iron has shown remarkable properties in connection with bearing surfaces.

PROFESSOR WILSON:—I think porosity could not have had much effect on the result because the greatest thing we had to fight against was porosity. We could do a fine job of polishing on a surface, but 95 per cent of the castings we made from different metals are, under the microscope, full of tiny holes. When we polish out one row we come to the next; so we had to do all our work on carefully selected non-porous surfaces. I think the abnormal results frequently observed with cast-iron are almost certainly due to the graphite that is segregated out around the grain boundaries and are something akin to the lubrication action by colloidal graphite.

CHAIRMAN MOUGEY:—In the case of a number of commercial oils the attempt is being made to capitalize the idea of adding fatty acids, glycerids, soaps or materials of like character. Has any one had experience in the use of these oils in service to indicate whether the theoretical value is borne out in practice, or whether troubles develop?

PROFESSOR WILSON:—One thing I did not mention about the static-fraction coefficient bears on that question. Some members may have seen the remarkable claims for "mineral" lard oil or something of the kind made by heating mineral oil with sulphur. Colloidal sulphur is said to be in it but cannot be found. We tried the effect of heating mineral oil with sulphur and found that the compounds formed raised the static coefficient and also increased the type of cut that is made in machine-tool work, at least in our tests.

J. WILLARD LORD:—There has been some talk about reclaiming oils and several firms are engaged in that work. Do you think that oil reclamation is feasible?

PROFESSOR WILSON:—I have no definite opinion. I see no reason why reclaimed oil should not be just as good as the original if the different kinds of oil are kept separate.

DR. W. H HERSCHEL:—I think we should use caution in keeping the two kinds of lubrication, complete-film lubrication and incomplete-film lubrication, separated. It

[17] Tests with greases are not satisfactory from this standpoint, because so much of the friction is in the mass of grease itself, rather than between the gear teeth.

[18] See 1920 Report of the Lubricants and Lubrication Inquiry Committee of the British Department of Scientific and Industrial Research.

is customary to speak of glycerin as a liquid that has no lubricating properties. It should be remembered, however, that this applies only to the special field of incomplete-film lubrication. On a friction test, I succeeded in getting the lowest friction with a 60-per cent sucrose solution. This shows that under certain conditions sucrose, or glycerin would show the same thing and could be used as a lubricant. I do not advise using it because it would not be durable.

C. O. BECH:—I had an experience with a bearing that was fitted so closely that although one could revolve it freely when it was mounted on a shaft, after putting on one or two drops of oil the bearing would seize. What is the explanation of that? Has it any connection with the clearance necessary for oil between the bearing and the journal?

PROFESSOR WILSON:—What do you mean by "seize"? What oil did you put on?

MR. BECH:—An ordinary lubricating oil was used. The bearing would bind to the extent that one could not turn it by hand.

PROFESSOR WILSON:—If you have a very small clearance, air is a wonderful lubricant, provided the speed is high enough and the load is low enough to keep it in. It may be that the film was so extremely small that the rate of shear of the oil was very high, but I cannot see why the bearing should seize.

MR. BECH:—Perhaps I should not say "seize." It seemed to me that a distortion took place in the bearing, due to an attraction of some kind, and that this caused binding or increased friction. The torque necessary to turn the journal on the shaft was increased from 5 to approximately 75 lb-ft. This information may be worthy of some consideration in assembling shops of plants building machinery of various kinds.

PROFESSOR WILSON:—I should say that the difference was due to the much greater viscosity of oil as compared with air.

O. P. SELLS:—After being started, the bearing could be spun easily with a couple of fingers. But it took a man's strength to break it loose. What was the reason?

PROFESSOR WILSON:—That is exactly what I showed; that the static coefficient at zero speed is enormously higher than at any other speed. It is 0.2500 for lubrication where there is not a good film. With an oil of high film-forming tendencies it will be around 0.1000. As soon as the speed increases it will drop to 0.0200. A little later it will go to 0.0020. A number of bearings in actual operation did so. The Sperry gyroscope bearings run as low as 0.0020 and one can actually get as low as 0.0007 by using air under heavier loads and high speeds. In other words, the friction coefficients vary four-hundredfold under those conditions. There is also the tendency of certain oils to solidify when cold and actually build up a gel structure that requires great force to break it loose. This is the main factor in cold weather.

THE CAR-OWNER VERSUS THE SERVICE-MAN

(*Concluded from page* 142)

the two horses we had in 1885. When we think of a farmer owning an automobile we must forget the question of the amount of his income. That is not the question. The fact is that he must have the automobile, just as he must have his mower or his binder. That man wants a job that is standardized to his economic needs as much as possible, and we should keep that need in mind.

We must keep broad thoughts in mind. We must look beyond the four walls of our offices and factories. There are great uncultivated land areas and coal and petroleum deposits south of the equator. How can we cultivate these great areas of land and develop these natural resources? All of the great manufacturing nations of the world are north of the equator, and they will have to supply the machinery.

Mr. Hoover sent me the letter he had received from South Africa and I wrote to several parts manufacturers. I said, in effect, that perhaps they had thought only of factory production methods within their own four walls and considered only what is best for the manufacturers. I advised them to enlarge their vision to include the world, because that is where the products that they manufacture can be sold. They all replied with the acknowledgment that they had been in error, that they believed they had concentrated too narrow mindedly in the designing of their products and that they must, if they are to utilize the full extent of these possibilities, think more in terms of the fields in which their products are to be sold.

I think these service meetings are very helpful. I hope that this annual meeting in Chicago will be a service meeting for some years to come, and that the owners and all other interested people will attend.

POWER LOSS IN PNEUMATIC TIRES

THE rubber laboratory of the Bureau of Standards is equipped with a special dynamometer for determining the power loss in automobile tires. Many standard makes of tire have been tested on this dynamometer. Some interesting figures have been secured. It is stated that an average 4-in. fabric tire, under conditions of normal load and air-pressure, will absorb approximately 0.90 hp. due to rolling resistance at a speed of 25 m.p.h. Under the same conditions the power loss in a 4-in. cord tire is approximately 0.60 hp., while a 5-in. cord tire represents a loss of 1.20 hp. It is estimated that from 80 to 85 per cent of this loss is in the carcass, the tread contributing 10 to 15 per cent and the tube probably less than 5 per cent.

RECLAIMING LUBRICATING OILS

AN investigation of the possibilities of increasing the quantity of used lubricating oil that can be reclaimed is being carried out by the Bureau of Standards. Experiments with a commercial type of oil reclaimer that involved increasing the temperature at which the oil was allowed to stand from 180 to 200 deg. fahr., increased the amount of oil recovered from 80 to 89 per cent. The data obtained show that the reclaimed oil is similar to new oil except as regards sediment. Further investigation is necessary to determine a satisfactory means for the removal of this sediment, which is probably carbon. In this connection it should be borne in mind that this increase in the amount of oil recovered may represent an increase in quantity at the expense of quality.

Discussion of the Minneapolis Tractor Meeting Papers

THE discussion of the papers presented at the Minneapolis Tractor Meeting of the Society consisted without exception of the remarks made at the meeting. Those who presented the papers were asked to reply to the discussion, and their comments are included in the discussions. A brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared.

In addition to discussion given below the discussion of Tractor and Plow Reactions to Various Hitches, by O. B. Zimmerman and T. G. Sewall, was printed with the paper in the July issue of THE JOURNAL. The discussion following the presentation of the paper by R. C. Schoen entitled Practical Road Construction will, it is expected, appear in an early issue of THE JOURNAL, together with the paper.

THE VALUE OF STANDARDS IN TRACTOR MANUFACTURE

BY P. M. HELDT

THE history of the systematic introduction of standards in mechanical manufacture is outlined, instances being given of the need for such standardization and specific reference being made to its value to tractor builders.

After mentioning the necessity of manufacturers maintaining a broad-minded attitude toward standardization, the author discusses steel and other standards, such as tractor hitches, belt speeds, connections between parts or machines that are made in different plants, screw sizes, lug attachment and general matters relating to the subject. The hope is stated that tractor manufacturers will appreciate the full advantage of cooperative effort and of mechanical standardization as one of its expressions.—[Printed in the April 1922 issue of THE JOURNAL, p. 270.]

THE DISCUSSION

CHAIRMAN O. W. YOUNG:—This is a live topic. There are many reasons why engineers and designers should keep it in the forefront of their thought. We have not done very much in the standardization of tractors, but it is a fertile field. We little realize how much S.A.E. Standards have entered into tractor production uptodate, even in small things. There is no reason why they should not go farther toward reducing production costs. The exhibit of the Society at the tractor show contained much food for thought.

One thing that ought to be emphasized whenever this subject is discussed, is that standardization, no matter how far it is carried, never means the sacrifice of individuality or originality in the product. It is surprising how many people still adhere to that old idea. Standardization used to be resisted. When the subject was first broached in connection with tractor design, the designers threw up their hands and said, Conditions vary all over the map and until we get together on some sort of common design we cannot do much standardizing. But standardization of details is the principal factor affecting production costs.

CHESTER S. MOODY:—We have used the S.A.E. Standards in our work. Naturally I shall talk particularly from the material end. We have run into a number of things with those standards. We have had trouble with some of them; others point a way toward a better development of our present standards. The manufacturer who starts with the heavy-type machines is apt to get into trouble as he has a tendency to run to larger sections. He must be careful to apply those standards to sections up to 1½ in. maximum. In our first use of the S.A.E. Standards in metals, we had a 3½-in. section. That is something a new man should know, and there should be information concerning the technical end, the effect of the different alloys on the penetration of heat-treatment.

In tractors that are carrying the heavy loads and high stresses we find that the bearing sizes sometimes are the determining factor. We should have reliable information as to the bearing pressures that different materials can stand.

I cannot say too much in favor of the standards we have had. Our experience has been altogether very pleasing. We have been able to buy steel quickly and it has expedited production in many ways.

The advantage of another factor, that of possibly narrowing our specification, comes in as production increases. One thing that is hard to standardize is the quality of the steel of a given analysis. Our protection is to pick reputable makers. Steel is something that we cannot standardize; I should not say we cannot; we hope that we may some day.

CHAIRMAN YOUNG:—Mr. Moody, by saying that you have to select your sources to assure the quality of the steel, do you mean that ordering from a number of different sources from the same specification would give you a wide range of variation in quality?

MR. MOODY:—That is exactly what I mean. We have had that particular experience. I was not able to specify where the material was to come from, but merely to give the S.A.E. Standard. The trouble came particularly in sizes. If I had received a higher-priced steel I might have expected different results. The trouble occurred not only in straight carbon-steel but also in alloy-steel. It is very common among those who are trying to produce high-grade work to specify sources, that is, probably two or three different sources; they are not necessarily confined to one.

A. W. S. HERRINGTON:—The trouble is largely a matter of organization. I believe it is not only possible but that it is good practice for the purchasing department to have an approved list of purveyors. It is then merely a matter of inspection upon receipt of the materials. You do not have to accept any pay for them if they are not satisfactory. You have that under your control.

W. M. MANSFIELD:—From the implement-manufacturers' standpoint the Society's specifications are a sort of penalty. We have to pay more for material. There are many parts that can be made of mild steel, or of a higher-carbon steel where the range is not important, at a less price than under S.A.E. Standards. Recently we have abandoned the Society's specifications on many parts that carried no particular load, and have gone to the cheaper grade of steel.

O. B. ZIMMERMAN:—That is the same question that has been before our Materials Committee. We find that we can adopt the S.A.E. Standards, so far as specifying No. 1010 and so on is concerned, but we can allow the manufacturer a 15-point range on that specification. Say, for instance, the Society's specification has a 10-point range. We will allow 2½ points above and 2½ below. In that way we can get away from the extra price. One point that it is well to note in the standardization is that the steel manufacturers charge an extra of $5 per ton when a lapping past the 20-point carbon is specified, and $15 per ton above the 50-point. Now in looking up your specifications and working them over, if you will be careful not to lap over that range and keep under the 20-point with one and over the 20-point carbon with the other and under the 50 and over the 50-point carbon, you can save considerable money, especially if you buy in a large tonnage.

P. M. HELDT:—The Society's steel specifications were prepared originally to meet automobile requirements. In a line of work where the requirements are less severe no one would recommend S.A.E. Steel. The requirements are probably the most severe in airplane work; next, in automobile work. These specifications are the best that could be written to meet those very exacting requirements.

G. A. YOUNG:—There is a great need for standardization in the tractor field in not only reducing the cost of the tractor itself, but also facilitating the renewal of tractor parts. The inherent difficulty in tractor standardization, of course, lies in the fact that the industry is really in the experimental stage and it is hard to say definitely what is right and what is wrong. We are getting to the point where we can standardize engine accessories with some degree of confidence that such standardization will not hinder development.

It would seem advisable to make the height of hitch adjustable between certain limits. Belt speeds will probably be reduced to two standards which in time the builders of belt-driven machinery will adopt. Insofar as possible basic machine parts in tractors should be standardized. However, I venture to make the assertion that there are many parts which will not be standardized for some time yet and I think one of these is the question of the lugs.

JOHN MAINLAND:—Personally we can see no reason why two belt speeds are not sufficient and three at the most. In fact, in the days when the steam engine was used almost universally to drive farm machinery there was only one belt speed. Although this never was considered a standard, all manufacturers adhered so closely to it that it might have been considered standard, and in selling threshing machines; clover hullers; silo fillers and corn huskers, the belt speed was never considered, because it was taken for granted. The situation at the present time is very different indeed and our first consideration today, in selling a machine, is to get the power with which it is to be operated in order to put on the correct pulleys to give the correct results.

Practically, all machines of the type mentioned have a very small range within which the number of revolutions of some part of the machine can operate successfully, and this is constant or practically so no matter what the belt speed. The fact is, that some means must be found of getting this speed no matter what the belt speed of the driving unit is.

It is true that the same belt speeds are not the best for all machines, but any tractor, unless its sale is very limited, must meet the varying conditions. Now, if one belt speed is such that it is more convenient for one kind of machine it is less so for the other and you cannot meet all machine conditions to the best advantage with the same belt speed. On the other hand, all belt speeds in tractors must be modified to meet the requirements of the whole range of power-driven agricultural machinery. If there was only one belt speed, this would not be so very difficult, because it would be definitely known what was required, but with the present range of belt speeds in tractors, this is a very complicated process because such a large equipment of pulleys and the like must be carried in stock.

We would like to correct one mistake in Mr. Heldt's paper. He says as follows:

> It is possible that this number of different speeds is necessary temporarily because of the requirements of the various types of power-driven machinery now on the market. The designers of these machines had nothing to guide them in determining the pulley sizes.

This statement is not true. The power-driven farm machinery now on the market was almost uniformly designed for a constant belt speed and at present the builders of them are compelled by the impossible number of different belt speeds in tractors to do the best in their power to have their machines conform to the speeds forced on them by tractor builders.

THE RELATION OF THE TRACTOR TO THE FARM IMPLEMENT

BY G. DOUGLAS JONES

STATING that the trend of tractor development must be toward the small tractor that is capable of handling all of the power work on a farm, the author quotes farm and crop-acreage statistics and outlines diversified farming requirements, inclusive of row-crop cultivation.

Tractor requirements are stated to be for a sturdy compact design to meet the demands of the diversified farm, which include plowing, seeding, cultivating, hauling and belt-power usage, and these requirements are commented upon in general terms. Consideration is given to farm implements in connection with tractor operation, and the placing of cultivating implements ahead of the tractor is advocated.—[Printed in the March 1922 issue of THE JOURNAL, p. 177.]

THE DISCUSSION

O. B. ZIMMERMAN:—This paper produces an interesting reaction on the speaker. After designing tractors for

about 16 years and internal-combustion engines for nearly 30 years, the analysis that Mr. Jones has given seems to me almost like a single patent-medicine. To meet all the possible requirements of a farm tractor with a single unit with all the necessary attachments, with all the necessary adjustments, does not look to me like a feasible proposition. We have, as I see it, a minimum of two types of machine to fulfill all the requirements. One of these must meet the plowing situation in which we have to deal with enormous strains, and the other one, the simpler proposition, concerns power cultivation, the handling of mowers, binders, and tools of that kind. My general analysis is that these two units will persist eventually; that in the course of development it may be possible to obtain an all-around outfit, but with the thought that I have given to the question I must say candidly that I do not believe the proposed solution is possible.

G. DOUGLAS JONES:—Mr. Zimmerman is, I think, holding very steadily to the plow line. I feel that the plow some day will be displaced, will be removed, and means of handling soil, other than by dragging a piece of steel of an angular shape through the ground, can be used to far better advantage than the method used today.

MR. ZIMMERMAN:—We hope that will come about, but I do not see it.

CHAIRMAN O. W. YOUNG:—The general specification that Mr. Jones lays down is pretty broad. Certainly we have not the type of machine to fill that bill to do a small percentage of the work implied as necessary. We know what Mr. Jones' company has done; we know what several other firms have done in an endeavor to give us a general-purpose machine. This is certainly one of the uppermost questions, speaking broadly, that is before the industry today. Some admirable progress has been made toward producing a general-purpose machine.

J. S. CLAPPER:—I agree with Mr. Jones in many things he has said about the tractor, although he has described the "ideal" tractor and it may be a long time before we get to it. When one considers that 45 per cent of the tilled land in the United States goes into row crops and that 55 per cent of the value of all crops produced is in row crops, one has a better idea of the need of a machine capable of doing more work than has been done. I believe we have reached a point where we cannot longer convince the farmer that a machine designed for plowing and beltwork is economical for diversified farming. It is all right in the wheat belt. I think much progress has been made in developing machines capable of doing 80 to 90 per cent of the farm work now being accomplished by horses and mechanical power. Until we can demonstrate to the farmer that the tractor will replace more than 20 per cent of his horses, I am afraid we will not get far in motorizing the farm.

I do not speak of the grain-belt section, for it has been demonstrated that the tractor is the most economical way of farming, but because the crops there are not row crops. I believe that the builder, instead of producing a single-purpose machine and trying to convince the farmer that he must shape his work to fit that machine, must study actual conditions and, if possible, give the farmer a machine that will do the work that he has to do on his farm.

PROF. J. B. DAVIDSON:—I think we may recognize two schools of designers that are working on the problem of the application of mechanical power to farm work. One is trying to displace the horse with a tractor that will perform all of the functions of the horse. It is along this line that present progress has been made. It is perhaps the first step. But I believe the other school, that is trying to capitalize the advantages of the internal-combustion engine, ought to have encouragement. For instance, present practice has not capitalized fully the advantages of light weight and automatic operation.

Future history probably will record that the designers who finally solved the problem got away from the pulling unit. We are doing many things now that are inconsistent from an engineering standpoint; for instance, we transmit the power of the engine to the drawbar and then pick it up again on the bull-wheel of some machine and transform it into a rotary motion. It may be necessary to have the heavy weight for traction to plow with, but if it is a matter of weight we might load our tractors with concrete or some other ballast to secure the extra weight. Perhaps we will build the engine in units so that it could be split into halves or quarters and a part of it used for lighter jobs.

CHAIRMAN YOUNG:—The diversity of opinion on this subject shows how big it is. It is stimulating to hear the different angles. We are probably thinking too much in terms of mechanism rather than in terms of operation. We have visualized mechanisms and tractors and means and have not done the fundamental research to meet the real issue, which is to accomplish the work rather than to consider the means whereby it is done. It is an infinite field.

F. N. G. KRANICH:—A thorough appreciation of the entire unit should be considered, as has been mentioned. The machinery that goes with the tractor is, after all, the important part of the outfit because it does the work with which the farmer is concerned. The tractor is only incidental and a means to an end.

Mention was made of the fact that the implements might be hitched to the front end of the tractor, but it is also possible that they might be hitched behind or even underneath and be just as useful. In either case, particularly with reference to hitching them to the rear, the operator may even ride on the machine where he can be in close touch with all that goes on. This would enable him to be more certain of its correct operation. With implements hitched to the front, the operator may be located too far from the implement proper and not be able to judge its work so clearly. The ears of the operator play a greater part than his eyes in telling whether the machine is functioning right. When he is located on the machine itself, trouble can be heard more easily than when he is located either behind or too far in front of the drawn machine. These points should be given serious consideration.

Using the power of the engine on the tractor as a means for driving the implement to which the tractor is hitched has already received considerable attention from engineers, but even then a thorough appreciation of the work that the implement does is the first consideration in designing what we term a general-purpose tractor.

A. W. SCARRATT:—The specification that has been laid down is practically ideal for a tractor of not more than two-plow capacity. Mr. Zimmerman states that power-farming has to include at least two types of machine and remarks have been made about different methods of tilling the soil. But there have been rotary tillers and other kinds of implements devised to turn over the soil that have never met with success because you cannot get the farmer away from his old way. So long as he persists in thinking of plows as the means of turning over his land, his idea must be accepted. If you are to plow land, machines large enough and strong enough to do the work must be used, and that puts them out of the cultivator class.

I think just such a machine as both Mr. Jones and Mr. Clapper have mentioned should be developed to take care of the farmer whose field does not cover more than 160 or possibly 200 acres and who farms in a diversified manner. When you get beyond that size of farm and come to the large farm where huge volumes of grain are produced, some of these considerations are eliminated automatically and one must have a tractor of a different kind, and that kind of machine cannot be a cultivator.

CHAIRMAN YOUNG: — That is true. Mr. Jones approached the subject purely from the standpoint of the general-purpose machine. That has distinctly one field; it applies to the requirements of a majority of potential tractor sales. From a manufacturing standpoint this is one of the most important phases of the subject because a small machine must be produced in large quantities to meet this market. The general-purpose tractor, the small machine below two-plow capacity that must be used as a cultivator, still remains the big market.

W. M. MANSFIELD:—At a recent meeting of the Society in Chicago the thought was brought out that engineering is a compromise. In designing a general-purpose machine we undoubtedly shall have to compromise to a great extent. It has been estimated that plowing constitutes about 20 per cent of the work on the average-sized farm in the corn belt. Possibly we shall have to compromise a little in the matter of weight and power in this 20 per cent to get a unit of the right capacity for the other 80 per cent. The general-purpose machine that is power-driven gives an opportunity to operate implements directly from the engine rather than through the bull-wheel as on the binder and mower.

A. ANDREWS:—In talking at the tractor show with a wheel manufacturer I asked him whether the hub was cast last or first. He replied that the hub and the spokes were cast first and that a tension was produced artificially before the rim was welded. He said that anyone who has done manufacturing appreciates that handling the work, rather than doing it, is the big item. Most people do not look at it that way. That is the problem on the farm; how a farmer will handle the farm is the real problem. When that is known we can easily find out what kind of machine is needed to take care of him.

CHAIRMAN YOUNG:—That always will be an open question in power farming. Certainly the methods of operating will change. They will be influenced to a great extent by engineers and manufacturers who take a step in advance by producing a machine that will do things in a little different way. The farmer will meet them half way or go them one better by using that machine in ways not thought of by the manufacturer. Then there will be another step by the manufacturer, and so on. This is going on now. We little dream how tractors will be used by the farmers. We are sometimes startled to see a tractor used for purposes different entirely from those for which it was intended. It would be very helpful if engineers would spend a little more time in the country studying or investigating some of the interesting things that the farmers devise.

A. H. BATES:—There is a wonderful field for the small tractor but, from an economical standpoint, I believe there is a decided tendency toward larger units. In fact, there is a persistent demand for a unit as large as one man can operate. It is easily shown that such a unit can be operated at a greater profit to the farmer than a small unit.

CHAIRMAN YOUNG:—There is no question about that from the standpoint of purely operating expense, but that situation might change over-night if prices were cut. Such a contingency might open up an entirely different viewpoint because the first cost of the tractor enters so largely into the fixed expense applying against it.

MR. BATES:—The point I wished to bring out is that the operating expense of the tractor is largely in the wages paid to the operator. If a large unit of three times the capacity of a small one can be operated for the same labor expense, it is self-evident that the cost of production with that machine will be less.

CHAIRMAN YOUNG:—If the farmer kept his books as the manufacturer does, that is the probable viewpoint he would take of it, but I do not think he does much bookkeeping.

MR. JONES:—Mr. Bates' statement is so broad that it gives an unlimited range. Conceive for a moment a tractor of 50 tons being operated more economically than a tractor weighing 1 ton. It is impossible. If labor cost were the only factor to consider, how pleasant it would be for the farmer. In reality the maintenance cost is really outrageous in many cases, and that is only one of the big costs. To eliminate the maintenance cost you would have to reduce the tractor to a compact, simple machine requiring little attention, but one that will keep up and give the farmer value for his investment. When we consider that plowing is 20 per cent of farm work, and that that is the load, I cannot see why we do not cease plowing and handle the soil as easily and probably better some other way and increase our crops to the volume they have in Europe. Why can we not develop our soil and treat it by mechanical processes by inexpensive, small machines that still have the power? We all know we are coming to a light machine. The airplane has shown that. We do not require the large machines of the past to do the same work today. I cannot see wherein a large machine is cheaper to operate than a small one.

MR. BATES:—I would like to enlarge on that. A small machine, a two-plow machine, weighs approximately 2400 lb. A number of six-plow machines that weigh under 7000 lb. are being produced at the present time. The cost of production should not be more per pound for one than for the other, except as the large production of the smaller machine might have some effect. Now, if we grant that, and also that one man can operate either machine, I think it will show that the cost of operation of the larger machine will be less. I have figures on two, three, five and six-plow machines. The man who came nearest to making a financial success was the man who operated the largest machine.

MR. JONES:—What was the limiting factor of the size of the farm? That must be considered first. I have taken 150 acres as the size of the farm wherein volume tractor sales must be taken into account. That is the point I would like to make very plain; that our volume sales are for the 150-acre farm. There we can operate with four horses, do fine work and still keep going. So why have six bottoms? Taking the crops throughout the year, when one portion is disced for corn, you do not plow it that same year, for the plowing has already been done. When the winter wheat has been put in and has been harvested, that too is out of the way. If rotation is kept up, which is absolutely essential to good fertility, plowing is limited; a large gang of plows is not needed. There was a time when a certain company had 55 bottoms in one unit.

A. R. SANDT:—Referring to the original and the maintenance costs, I do not believe that it is impossible to design and produce a tractor that will have a low maintenance cost. One can be produced that will have a low

maintenance cost and also have a low selling cost. One thing we fail to impress upon the farmer is that when he is buying a tractor he is buying a production machine. The tractor is a production tool and prices will have to be raised so that a machine can be turned out that will give the farmer a minimum maintenance cost.

E. R. GREER:—It is a mistake to figure that, because a farmer has a 50-acre farm, he must have a machine to do everything on that farm. I do not see any reason why he should not have a machine for row-crop cultivation and why a group of farmers should not have a suitable machine to do the plowing for everybody. A little two-plow machine will not plow more than about 5 acres per day. You have to get more speed, and cover more acres per day, to do it right if you have a big plowing job to do. Why can they not have machines in each community to do the heavy work, and have light machines to do the cultivator work?

PROFESSOR DAVIDSON:—I do not know of any successful community ownership, but the contract proposition works very successfully in the West. A large number of tractor contractors on the Pacific coast plow for a certain sum per acre or per day. This plan provides personal responsibility for the machines.

The question of the larger plowing-unit and the smaller cultivating-unit must be a compromise, unquestionably, because more power is needed for plowing than for cultivating. If it is a compromise, then this "ideal" machine proposed by Mr. Jones will have more power for cultivating than is necessary, and will be a little limited in power for rapid plowing. Such a tractor will come into competition with the horse in the intertilled-crop area where the best farmers use five horses and are able to plow perhaps 4 to 5 acres per day. If a farmer can do his intertilling or cultivating with a unit that will increase his capacity in plowing over this amount, it will appeal to him.

CHAIRMAN YOUNG: — A compromise machine apparently is one that would not be too heavy for cultivating, not merely from the standpoint of soil-packing but from the standpoint of economy of operation, and still would be large enough to be economical and profitable as a plowing unit.

MR. GREER:—I did not mean to give the impression that I advocate a machine being owned by the community when I said there could be one machine in the community, but rather, as suggested, that some one contractor should do the heavy work. In our operations in the city many of our customers have speed-trucks but contract with us to do the heavy work and heavy hauling.

MR. ANDREWS:—Almost every farmer has a Ford, and it can be proved that an attachment can be furnished for $100 which will do all the plowing on a 150-acre farm. The farmer can buy a cultivator with a motorcycle engine, similar to what Mr. Parrett had at the show, at a production price; so he can afford to have two machines. Here you have the lowest fixed charge that will take care of the work.

MR. SCARRATT:—What about the maintenance charges on the Ford?

MR. ANDREWS:—That is a matter of personal opinion on the part of different individuals.

MR. CLAPPER:—A good many people talk about cultivating machinery who do not know what is required in cultivating row crops. They have not been on a farm and actually spent time in cultivating different crops. We are discussing two different subjects; one is the smaller farm, where the volume of tractor business is coming from, the small farm where there are only 20 to 30 acres in corn, probably 40 to 50 acres in wheat and oats, and all the ground is not plowed at the same time but at different seasons of the year. When it comes to the large farms of the wheat-belt section, the cultivator is out of place. The average farm where there is diversified farming, where the principal crops grown are row crops, is in the central eastern part of the United States. That is where the "ideal" machine that Mr. Jones explained will be used if it can be built or developed, and I believe it can be developed and can be produced profitably. A great many people are wrong as to what is required to cultivate row crops. You cannot take a Ford car and put an attachment on it and hook a cultivator behind it. You have not the clearance in the first place.

MR. ANDREWS:—I did not say that; I said just for plowing.

MR. CLAPPER:—There is more to cultivating row crops than the average fellow thinks, unless he has had experience.

CHAIRMAN YOUNG:—Whenever this subject is opened up it is always a grand free-for-all. While we have skipped around and touched on many different phases of the subject, they all bear on the same thing. We have been consistent in that we have talked, to a great extent, of the relation of the tractor to the implement or its operation. This subject is one on which you never start at the beginning or finish at the end; you grab hold somewhere in the middle and hang on as long as you can and go as far as you can.

EUROPEAN INDUSTRIAL OUTLOOK

UNLESS we entirely misread the ascertainable facts of the economic life of the chief European countries at the present time, what is really occurring is that Europe is rapidly curing herself from the bottom upward, so to speak, instead of from the top downward. At the top, in politics, public finance and the direction and administration of all governmental affairs, we see confusion, conflict of purpose, uncertainty and blundering; but at the bottom, in industry, trade and those things that concern the mass of society, we see everywhere steadily increasing activity, confidence and certainty of motion. Despite all handicaps, the tide of production, whether in agriculture or in industry, is continuously rising in all parts of Europe except perhaps Soviet Russia; and as they produce more, the peoples of Europe consume more, live better and establish their entire economic life on a firmer foundation. This being the case, let us squarely accept the probability that it is better for them that projects for great international loans to them should fail rather than succeed. And to this probability may perhaps be added another, namely, that it will ultimately be found that the politicians have got nowhere with their schemes for settling such vexed questions as that of the German reparations, that of the opening up of Russia to the trade of the world, and so on, but that somehow or other through the silent operation of the great forces of industry and trade, as carried on by the undistinguished mass of the people, in the several countries, inevitable and therefore acceptable solutions of all of these vexing questions will finally have been arrived at. —A. R. Marsh in *Economic World*.

Vol. XI August, 1922 No. 2

Some Fundamental Characteristics of Present-Day Buses

By R. E. Plimpton[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs and Diagrams

THE author enumerates the distinctive features of buses designed for city, for inter-city and for country service and comments upon them, presenting illustrations of these types of bus. Steam and electric motive power are discussed and the chassis components for bus service are considered in some detail. The general types of bus body are treated, together with the influences of climatic conditions and local preferences.

Comfort and convenience factors are discussed at some length and the problems of heating, lighting and ventilation are given constructive attention. Fare-collection devices and methods are commented upon, and the State and local legal regulations are referred to in connection with their effect upon bus operation.

Illustrations are included and a table showing condensed specifications for city buses is presented.

ANY division of the types of vehicle used for buses must be arbitrary, but for convenience we can consider them as applied in city, inter-city and country service. The city bus is designed for use on good pavements. The seating capacity is high, 20 or more passengers, but high speed is not essential. A maximum of 20 m.p.h. is often considered ample. Ability to thread through traffic and to move passengers quickly, on and off, is required. Ordinarily, overload capacity should be provided, so that standees can be accommodated during the rush hours.

The double-decker, a dense-traffic vehicle, has been developed highly through years of service in London and New York. Table 1 gives specifications for the latest types used in these cities. The L-type bus of the Fifth Avenue Coach Co. is distinguished by the low floor, the first step being at the curb and only one other being required to reach the floor of the bus. Increased seating capacity, without any increase of weight, has been secured in many recent double-deckers. A sample now operated in Chicago seats 69 passengers, with a total vehicle weight of only 157 lb. per seat. Previously, about 200 lb. per seat had been considered good practice. This Chicago bus is probably the largest double-decker ever operated commercially. Fig. 1 shows the plan of the lower deck of what is said to be the largest double-decker in England, a Leyland 63-seater carrying 34 passengers on top. Notice the space for a loading well at the lower entrance.

Covered upper decks have been tried out in New York City and Chicago, but have proved popular only in bad weather. Double-deckers in London, England, and Toronto, Canada, have been fitted with blankets for each top-deck seat, in the effort to build up the load factor, these being illustrated in Fig. 2. The so-called double-single-decker has been tried in England; the entire top deck of this vehicle can be detached for winter service.

[1] M.S.A.E.—Associate editor, *Bus Transportation*, New York City.

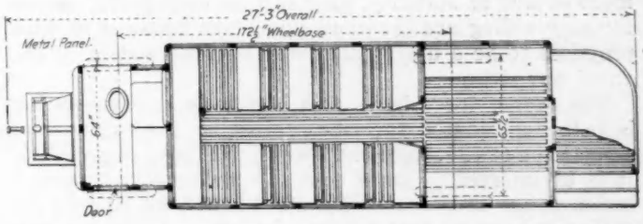

Fig. 1—Plan of the Lower Deck of an English Double-Deck Bus Carrying 63 Passengers

the stairs being removed and the hatchway closed by a trapdoor. One vehicle of this type has a capacity of 29 passengers as a single-decker, and of 54 passengers, half below and half above, when both decks are in use. However, the single-decker shown in Fig. 3 has by far the largest field as a city bus. A few of these designs are described in Table 1 and there are many others of a similar type under way by other builders. Long wheelbase to give loading capacity, a wide rear gage and a narrower gage on the front to give stability and a small turning-circle, low frame-height to give quick passenger move-

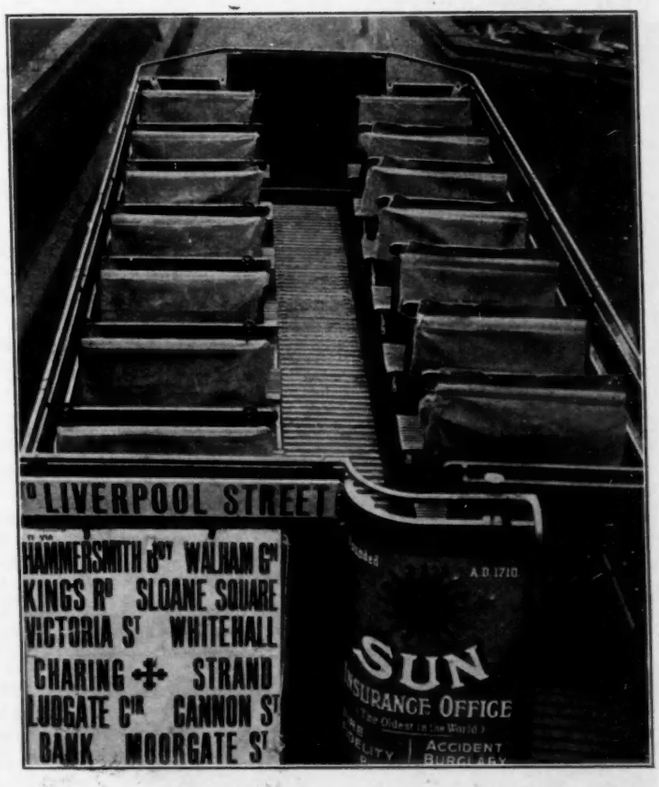

Fig. 2—Tarpaulin Lap Robes Used on the Upper Deck of the London Buses

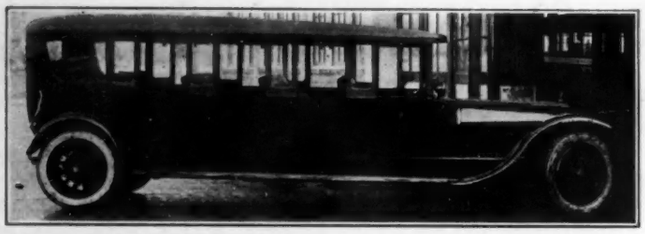

FIG. 4—CALIFORNIA STAGE ON A REBUILT AUTOMOBILE CHASSIS HAVING A CAPACITY FOR 14 PASSENGERS ON FIVE CROSS-SEATS

ment as well as stability, long springs and special devices for easy riding are the more important features of what promises to be a design that will be used widely in and about our cities.

The design for a light, fast, single-deck, one-man bus is being considered for city service by the engineering association of the American Electric Railway Association. It is of interest to know that experts on city transportation favor three sizes, for 21, 25 and 29 passengers, with a maximum floor-height of 26 in. A smaller size, for 16 passengers, has also been discussed.

Most city buses have a central aisle, with cross-seats on each side. In a modified form the seats near the service door are of the longitudinal type, thus providing a space for standees or for those making short trips. This is being applied in short-haul work, while there is a tendency to use the unmodified cross-seat type in suburban work, and even for inter-city service.

THE INTER-CITY BUS

The inter-city bus, such as is shown in Fig. 4, is smaller and faster than the city bus. From 12 to 20 seats are provided for the long runs of 20 miles and upward. These vehicles are known as stages in the West and particularly in California, probably because of familiarity with the term to designate a horse-drawn omnibus. The stage usually is built with three or four rows of seats running all the way across the body, each having its own side doors. It resembles an enlarged touring car and, of course, that is what it frequently is. Comfortable riding is desired, rather than the ability to handle crowds. The floor level is kept as low as possible without decreasing the road clearance below 7 in. The center of gravity is kept down to eliminate sway, with its consequent danger, and undue wear on tires and wheel bearings.

The average speed in Western inter-city service is high. Orders to drivers on a large system in California are to make 32 m.p.h. on well-paved highways and 35 m.p.h. is the legal speed limit. However, there are stretches where it is hard to keep down to this speed. For example, on the desert floor west of El Centro, Cal., a broad concrete pavement stretches away for 30 miles. There are no cross-roads and no habitations are in sight; there is no obstruction to view and very little traffic. With a high-powered car, the driver who will keep down to 35 m.p.h. is unusual. The actual speed over such stretches is from 40 to 45 m.p.h. and, occasionally, 50 m.p.h. The chassis and body should be of the minimum weight, consistent with long life and durability. The improvements being made in highway systems will, it is believed, lead to the use of even lighter chassis than are used at present.

FIG. 3—SINGLE-DECK, 25-PASSENGER BUS FOR CITY SERVICE

The stage used in the West is, as a rule, a rebuilt product. A high-grade touring car is bought second-hand, the frame is lengthened 4 to 5 ft., and a heavier differential, heavier springs and heavier tires are installed. It is realized that these vehicles are expensive, in both first and maintenance costs, since they are always in the "special" class; but Western operators have used them because they could not buy a chassis that would carry the long bodies up steep grades and at high speeds demanded by Western operating conditions. One design at least, that is included in Table 1, is now on the market, and there are indications that others will be avaliable soon for inter-city service, not only on the Pacific coast, but also in many other parts of the Country where the large rebuilt touring car has been used heretofore.

THE COUNTRY BUS

The country bus may start nowhere and end nowhere, as is said of some of them, but usually it runs through rural districts to a trading center or a point where connections can be made with some other form of transportation. This service does not require particularly high speed, but the bus should be able to keep going over poor roads, even when they are covered with mud or snow. Travel is light in this service; so the vehicles used are small. Touring cars of five and seven-passenger capacity may be operated when the roads are particularly bad, giving way to larger buses, up to 18-passenger capacity, during the summer months. One trip a day is often the custom, to town in the morning and returning in the middle of the afternoon. Thus, the operator has the time to pick up light freight for delivery along his route; or he may be a star-route contractor for the Post Office Department, in which case he may carry passengers and freight so long as his contract is properly performed. Therefore, the country bus should be built to carry both passengers and freight. Most operators seem to use the standard passenger vehicle, car or bus, and carry the packages inside or outside, wherever there is vacant space. A space for packages is placed at the front of the vehicle in some designs, with the rear given over to seats.

A convertible vehicle would be particularly useful in consolidated school service, where many buses are now operated only 3 or 4 hr. per day. The seats are removable in one design, so that the school bus can be changed quickly to a light delivery truck. Several combination bodies are on the market, designed to carry both passengers and express, but they have not been used to any extent by bus operators so far.

A transferable body has been suggested for school use, although it might be applied by the operator of country buses also. This would be mounted on a motor-vehicle chassis when the roads were good, but transferred to a horse-drawn vehicle, on wheels or runners, when they are

impassable. The fact that this has been proposed seriously indicates the need for properly designed country buses. The field for them is enormous, and it should be possible to provide operators with a light, sturdy, economical bus for use during the 12 months of the year. Some engineers contend that good roads must come first. Yet bus service is being given on thousands of miles of unimproved roads. The life of the vehicles used is short, and some operators believe it economical to turn them in yearly for new ones. Here is a real problem waiting for automotive engineers to solve. The bus for city service is receiving attention from a large number of sources, but its country cousin is, as yet, almost neglected.

Steam and Electric Motive Power

Before taking up the details of chassis and body used for the standard gasoline bus, other types that have been applied will be noticed. The gasoline-electric bus shown in Fig. 5 is used commercially in England, some 175 of the Tilling-Stevens chassis being operated in London, and

TABLE 1—CONDENSED SPECIFICATIONS OF TYPICAL CITY BUSES[2]

Unit	London General Omnibus Co., Type S	Fifth Avenue Coach Co., Type L	Imperial	Fifth Avenue Coach Co., Type J	Mack	Republic	White	Duplex	Fageol
Number of Seats	54	51	30	25	25	25	25	23	20
Approximate Floor Height at Entrance, in.	31	18	26½	25	32	28	28	27	18½
Wheelbase, in.	179	175	195	172	180	168	198	160	188
Front Gage, in.	72½	67	66½	68	58¼	66	58½	56	70
Rear Gage, in.	70	72	71	71¼	60	66	60¾	62	70
Total Weight, lb.	9,380	10,150	9,500	6,900	8,850	7,900	8,900	6,500	6,800
Body Weight Only, lb.	2,800	4,000	3,000	2,100	2,700	2,400	3,500	2,300	1,600
Engine, Bore and Stroke, in.	4.26x5.51	4x6	4⅛x5¼	4x6	4¼x5	4⅛x5½	4¼x5¾	4x5¼	4¼x5½
Type of Valves	L-Head	Sleeve	I-Head	Sleeve	L-Head	Sleeve	L-Head	L-Head	I-Head
Engine Speed, r. p. m.	1,050	1,400	1,600	1,400	1,275	1,800	1,650	1,600	1,800
Horsepower	34	50	47.½	50	37	50	50	42	62
Fuel Tank Capacity, gal.	25	40	30	35	25	30	35	25	28
Fuel Feed	Vacuum	Gravity	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum
Carbureter	Zenith	Zenith Special	Zenith	Zenith Special	Schebler	Float-Feed	Own	Stromberg	Zenith
Cooling System	Pump. Tubular Radiator	Thermo. Tubular Radiator	Pump. Tubular Radiator	Thermo. Tubular Radiator	Pump. Cellular Radiator	Thermo. Tubular Radiator	Pump. Cellular Radiator	Pump. Cellular Radiator	Pump. Cellular Radiator
Ignition	Magneto	Magneto	Magneto	Magneto	Magneto	Magneto	Magneto	Battery	Battery
Clutch	Single Dry Plate	Single Dry Plate	Multiple, Dry Disc	Single Dry Plate	Multiple Dry Disc	Multiple Dry Disc	Single Plate	Multiple Dry Disc	Multiple Dry Disc
Transmission Speeds	3	4	4	4	4	4	4	4	4
Control	Center	Side	Center	Side	Center	Center	Center	Center	Center
Universal-Joints	Fabric and Metal	Fabric	Metal	Fabric	Metal	Metal	Metal	Metal	Metal and Fabric
Steering Gear	Worm and Nut	Worm and Nut	Screw and Nut	Worm and Nut	Worm and Gear	Worm and Nut	Worm and Sector	Worm and Nut	Worm and Nut
Front Axle	I-Beam Section	I-Beam Section	I-Beam Section, Dropped Center	I-Beam Section	I-Beam Section	I-Beam Section	I-Beam Section	I-Beam Section	I-Beam Section
Rear Axle	Underslung Worm	Internal Gear	Internal Gear	Worm, Semi-Floating	Double Reduction	Internal Gears	Double Reduction	Worm	Underslung Worm
Wheels	Cast Steel	Steel Disc	Steel Disc	Hollow Spoke	Artillery	Artillery Cushion	Cast Steel	Artillery	Disc
Front Tires	Solid, 41.30x4.73	Solid, 34x5	Cushion, 36x6	Cushion, 34x4	Cushion, 34x5	Cushion, 34x4	Solid, 36x4	Pneumatic, 35x5	Pneumatic, 36x6
Rear Tires	Dual Solid, 41.30x4.70	Dual Solid, 34x5	Dual Cushion, 36x6	Cushion, 34x6	Dual Cushion, 34x5	Cushion, 34x8	Solid, 36x7	Pneumatic, 38x7	Pneumatic, 36x6
Spring-Suspension	Semi-Elliptical, Volute Auxiliary	Semi-Elliptical, Progressive	Semi-Elliptical, Compensating Underslung	Semi-Elliptical, Progressive	Semi-Elliptical, Rubber Blocks	Semi-Elliptical	Semi-Elliptical	Semi-Elliptical, Snubbers	Semi-Elliptical, Underslung
Braking System	Two, on Rear Wheels	Drive Shaft and Rear Wheels	Drive Shaft and Rear Wheels	Two, Expanding on Rear Wheels	Drive Shaft and Rear Wheels	Drive Shaft and Rear Wheels	Drive Shaft and Rear Wheels	Two, Expanding on Rear Wheels	Two, Expanding on Rear Wheels

[2]The first two are double-deck buses; the remainder are single-deck buses.

others in the smaller towns. This consists of a gasoline engine direct-connected to a dynamo. The latter is electrically connected to an electric motor, which drives a worm rear-axle through a propeller-shaft. The control is by a speed regulator of the multiple-contact type, operated by varying the resistance in the shunt field of the dynamo, and by shunting the series field of the electric motor.

Storage-battery buses are used in Chicago for carrying passengers between the railroad depots. In another city the street railway is now trying out a battery vehicle in short-haul feeder service. This bus is fitted with pneumatic tires and makes about 12 m.p.h. in ordinary operation. The limited speed and battery capacity have worked against the battery-driven vehicles, although they undoubtedly have a field for short runs on good pavements.

The trolley bus shown in Fig. 6, a road vehicle using the overhead system of the electric railway, is making headway on this side of the Atlantic, as shown by recent installations in Toronto, Canada; Minneapolis, and Los Angeles, Cal. The system on Staten Island, New York City, is to be extended by the use of 15 trolley buses now ordered for the New York City Department of Plant and Structures. Some of these will be used on a City Island line, in the Borough of the Bronx, New York City.

Many of the trolley buses look like rail cars fitted with rubber tires. However, there has been a tendency of late to follow closely gasoline vehicle design, thus using standard parts and making it possible to change from one type to the other by installing a gasoline engine and transmission apparatus.

A front-drive design has been worked out for the buses used in Leeds, England. The electric motors are under the front, and can be removed for repairs. It is claimed that this construction improves adhesion and traction effort, reduces the consumption of electric energy and makes possible a 14-in. floor level.

The steam-propelled bus is not in commercial operation at present, although several experimental vehicles are being developed for such service. The Clarkson steam buses, which were popular in London because of their speed, quietness and ease of control, stopped operation in 1919, mainly, it is said, because of the increase in fuel cost.

Chassis Components for Bus Service

The principal parts of the bus chassis savor strongly of motor-truck practice, and bus individuality is gained by such features as more powerful engines, longer springs, battery and lighting generator and the like. Four-cylinder engines, with L-heads, are used on the majority of buses. A few designs for city service have sleeve-valve units. Some I-head types are being supplied, mainly for the fast inter-city work. Many operators are talking in favor of six cylinders, because of the smoothness and flexibility they assure.

The data given in Table 1 indicates that engine speeds of from 1400 to 1800 r.p.m. are common, at least for city buses. These speeds need not be maintained for long periods, but they are essential, as is also quick acceleration, for threading city traffic, passing other vehicles on the open road and maintaining schedules when stops are frequent. Quiet operation at slow speeds is essential also.

Governors are not common on vehicles designed for bus operation. A driver to whom the lives of passengers can be entrusted will not require a governor to safeguard the vehicle.

In many localities the law requires that the gasoline tank be filled from outside the bus. Tanks therefore are being placed at the rear of the frame, or at the side between the wheels. Another arrangement is shown in Fig. 3, where the tank is placed under the floor of the body, and filled through a port-hole in the side of the body.

Ignition is mainly by magneto, this being favored by many operators because a magneto is easy to replace. With the growing practice of installing a battery and a lighting generator, battery ignition is likely to be given more consideration.

Thermosyphon and pump circulation are both used on buses. The latter system is used in the majority of the designs listed in Table 1. Radiators with replaceable cores are being developed for bus service. They illustrate the tendency to provide parts that will decrease the time required for adjustments or repairs.

The exhaust system is usually fitted with a valve connection so that the body-builder can install a heating system. The end of the exhaust pipe, and this also applies to heater outlets, should be placed at the extreme rear so that the gases are discharged back of the body and not underneath it.

A smoothly operating clutch is an essential on buses. Jars and jerks not only increase maintenance costs, but they mean also continual discomfort to passengers. The service is so severe that this unit should be of liberal size.

Bus transmissions as a rule are of the four-speed sliding-gear type. They should be designed to stand up under a service involving 10 or more stops per mile and upward of 50,000 miles of operation in a year. The strain is intensified if the driver jumps to second or third speed when starting.

The maximum speed should be just high enough to maintain schedules from a transportation point of view, with a fair margin allowed to make up lost time. Passenger comfort requires steps between gears that are as nearly equal as possible. The low-gear speed must have power enough also to pull the vehicle through loose dirt, mud or snow.

Universal-joint design is especially important in the long-wheelbase bus. Bearing supports as well as extra joints are used to overcome the whipping effect of the long propeller-shafts. The angularity of these shafts is comparatively slight, so that full advantage can be taken of the shock-absorbing properties of the fabric joint.

The rear axle for the city buses is being made wider, of 72 and 74-in. gage, than on heavy motor vehicles. The underslung type of worm-gear axle is being used to a considerable extent to gain low floor-levels, while front axles with a center dropped sharply down between the pads and the yokes. are being provided for city service.

Frame construction and proportions have been influenced appreciably by the development of the city-type bus. The law limits the overall width, so the bus body has had to be lengthened to get capacity. The overhang beyond the rear axle and in the back of the frame is limited also by considerations of safety and good design. All this has led to the long wheelbase, which seems to be longer with every new design. Frame sections have had to be made deeper on account of the great distance between the wheels. The frames have been widened at the same time to care for the 7 and 8-ft. bodies they must support. The demand for low floors has again been taken out on the frame, which is made with a kick-up over the rear axle so that the central part can be kept close to the ground. On one new

design, shown in Fig. 7, this kick-up is found at both the front and the rear axles.

Owing to the severe service and the need for the utmost safety, the steering-gear and the brakes should be heavier even than for truck designs. Easy steering is important, to save the driver's strength.

A propeller-shaft brake is used on a number of bus models, undoubtedly because of its simplicity and the ease of securing equal braking on the rear wheels. On the Pacific coast four-wheel hydraulic brakes have been tried, for reasons of safety and to increase the life of the rear-wheel tires. The four-wheel air-brakes now being developed for heavy motor vehicles should be useful for large buses also.

Riding comfort is a bus requirement that has received close attention in the new designs. While underslung springs are installed principally to lower the bus floor, they undoubtedly improve the riding qualities of the vehicle. The change in wheelbase length that occurs on one side when one wheel strikes an obstruction is much less with the underslung construction, because the center of the rear axle is almost in line horizontally with the front eye of the spring, instead of being several inches

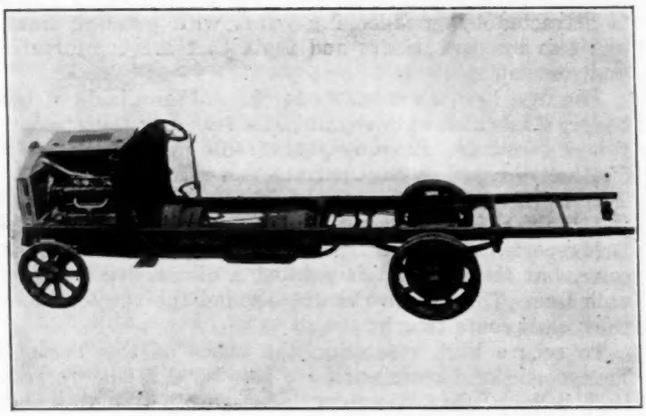

FIG. 5—CHASSIS OF THE TILLING-STEVENS GASOLINE-ELECTRIC BUS USED IN ENGLAND

below it, as with the conventional overhung construction.

Most of the bus designs have an auxiliary suspension that comes into play with heavy loads or severe road-shocks. The simplest is the so-called progressive spring, with extra leaves mounted below the main spring but at a flatter camber. Much the same effect is secured on the London buses by a volute spring attached to a bracket on the frame; or, the ends of the main spring are carried in sheaves, rubber blocks or small springs mounted inside the hangers. While these devices are used particularly on the rear springs, the front axle also is being better sprung, not only to protect the engine, but to carry the heavier loads thrown forward by the long wheelbase. Another method is to use the shock-absorbers developed for private passenger-cars. The pneumatic type, for example, is fitted to some of the California stages.

Pneumatic tires are almost universal on the small buses, but on the heavier types the large single pneumatic tires have the disadvantage of throwing the body high up into the air. This is being overcome by the application of dual tires on the rear wheels, which permits the use of six tires of the same size. The development of the "doughnut" design will help here, provided the brake diameters can be decreased to correspond.

Many operators in the cities are using solid or cushion tires, mounted on a resilient rim or cushion wheel. This

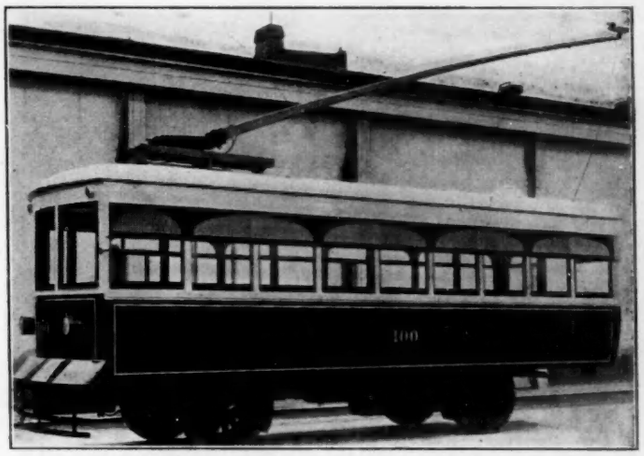

FIG. 6—A BUS OF THE SO-CALLED TRACKLESS TROLLEY TYPE

combination seems to work out satisfactorily on fairly good pavements, although it has proved too heavy for the rear-axle mechanism on certain buses working over rough roads.

BUS BODIES

The old horse-drawn stages undoubtedly furnished the inspiration for modern bus bodies, and later technique seemed to be based also on the bodies built for motor trucks. At any rate, many of the first bodies were heavier than necessary for either economy or comfort. The timbers were too large, the ironing was too heavy and too much of it was used. Then, cheaper bodies were demanded; the pendulum swung too far the other way; bus bodies loosened up and became noisy; they began to fall to pieces and repelled instead of attracting passengers.

At first, quantity production of bus bodies was difficult because chassis mounting-dimensions were not standardized. Frame-widths and lengths, the location and the dimensions of rear wheels, the position of drivers' seats and controls and the height of the frame from the ground all seem to be different on every chassis. Bus bodies are now being turned out in quantities, however, partly because the sills can be altered to fit different chassis, and partly because of the great increase in the demand. The price and the weight have been decreased greatly, and, at the same time, there have been many improvements in detail construction.

The mounting on the chassis usually is designed to keep the floor as near the ground as possible. Many bodies now are set directly on the frame, so that the floor is only its own thickness higher. Longitudinal sills are placed between the frame side-members and supported between them. The part of the body projecting beyond the frame may be carried on cross-straps that extend the full width and are supported at the ends by pressed or built-up brackets riveted to the side-members; or, the support may consist of channels carried across

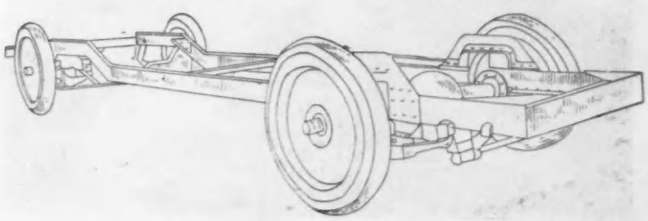

FIG. 7—BUS CHASSIS HAVING A KICK-UP AT EACH END RESULTING IN A FLOOR LEVEL THAT IS ONLY 19 IN. ABOVE THE GROUND

FIG. 8—CONVERTIBLE BODY USED FOR ALL-YEAR SERVICE, THE ROOF POSTS BEING ENCLOSED BY DOUBLE CURTAINS IN THE WINTER

under the main frame and bent so as to carry the outside edges of the body. These are riveted to the side-members by structural shapes.

In general, bus bodies are built up on a hard-wood framing, of ash or oak. Dies for the all-metal body would be too expensive, even should such construction stand the weaving and twisting to which semi-flexible chassis-frames subject it.

Panel material may be wood, sheet-metal or composition. Sheet-metal is applied usually as a sheathing, as is also sheet-aluminum. A wood veneer, protected on the outside by sheet-steel, is sometimes used. This material, it is claimed, has the resiliency of wood, and the easily finished surface of sheet-metal. This veneer, or plywood, is also made up as roofs, or used as a ceiling to furnish a smooth surface over roofs of tongue-and-groove board.

Climatic conditions and local preferences both seem to determine the type of body used in any given section. The open body is popular in England, where it is fitted to so-called motor coaches or char-a-bancs. The seats are unbroken across the body and are reached by individual doors. As a rule, the roof can be folded back. In this Country such a vehicle is favored in the South and on the Pacific coast; also, it is used in large cities and in the National parks where sight-seeing is the reason for presence of the bus. Sight-seeing buses work mostly in warm weather, but in some parts of the Country, as in New York State, an open convertible body, such as is shown in Fig. 8, is used the year around. This has a permanent roof supported on pillars that are built into the sides of the seats. The open sides are covered by double curtains during the winter.

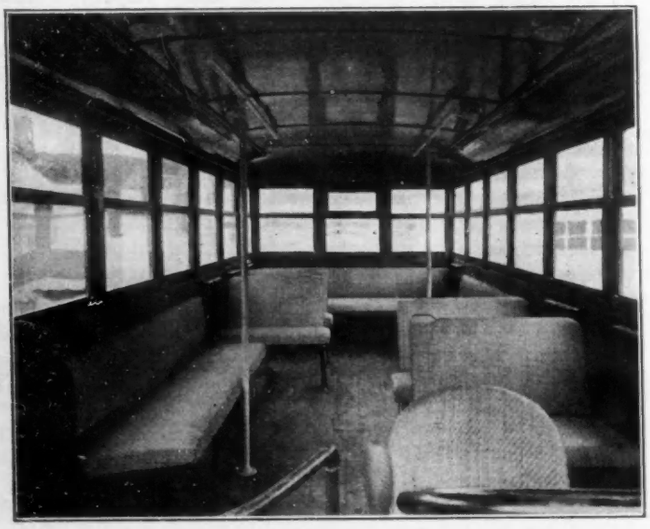

FIG. 9—THE SEATING ARRANGEMENT OF A BUS FOR CITY SERVICE WITH VERTICAL AND HORIZONTAL BARS TO TAKE CARE OF THE STANDEES

The closed type of body is found generally through the North, East and Central parts of the Country. This body, with two longitudinal seats, is popular with operators because of its wide central aisle, large standee capacity and good ability to load and unload passengers. The longitudinal type is not so comfortable on long runs of 30 min. or more, where the passengers settle down and are not boarding or alighting at frequent intervals. In country service and for large single-deckers in city or inter-city work, it is being replaced by an arrangement such as is shown in Fig. 9, in which both cross and longitudinal seats are used.

COMFORT AND CONVENIENCE FACTORS

The success of most transportation systems depends upon their ability to attract a group of riders who travel not of necessity but because the service given is attractive and its use is a pleasure. This profit-making group is attracted by good-looking buses with pleasing lines, and also by steps, doors and seats that are comfortable and convenient.

The first "convenience" factor is on the outside of the body. The color of the paint has transportation value. Where buses are numerous, each route or line can use a distinctive color, so that patrons can recognize it easily. The electric railways operating buses are naturally painting them the same color as their rail equipment. In Bridgeport, Conn., all of the buses are painted the same color, but the belt rail is painted a distinctive color on each line. This stripe running around the outside identifies each route clearly.

To secure high visability, the buses of the Toronto Transportation Commission are painted a sagamore red. It is believed that this color induces both employes and passengers to keep the paint on the vehicles in better condition, and that accidents are reduced because the operators of other vehicles exercise greater care.

The would-be passenger, having picked out the right bus, is now ready to enter; but first he must allow passengers to alight, since it is not practicable to provide door space for two conflicting streams of travel. If he is to enter comfortably the actual step-height will not be more than 15 in., although from 4 to 6 in. can be gained by curb-loading. Tests on trolley-cars have proved that 15 in. should be the maximum step-height. Three steps, with one 16-in. and two 14-in. risers, showed an average loading and unloading time of 2.50 sec. per passenger. This was cut to 1.75 sec. per passenger, however, when the change was made to one 15-in. and three 10-in. risers, each of the four being slightly wider than the three used in the first test.

The width of steps should be at least 12 in., although this often is limited because of the necessity of keeping within the body lines, and clear of the chassis frame. The steps should be shod with safety tread, for the good of the passengers and to prevent wear. In current designs, the steps are of permanent construction, the outside folding type can be used but is not particularly satisfactory as regards durability or safety. Two steps only are needed with the low-frame buses, and these can be arranged to fit in the body very nicely.

The simplest form of door, assuming that the entrance is covered at all, is the collapsible gate used in

Southern California. But more substantial construction is required in many parts of the Country. Several types of door are available. The sliding door frees the full width of the entrance, but makes necessary an expensive opening in the body. Two-leaf folding or jack-knife doors are therefore in more general use. These fold inward as a rule, as the outward folding type is frowned upon by the law-makers. Hinges at the front permit carrying the opening mechanism across to a handle that can be operated by the driver. The opening of the door may automatically turn on the step light at night.

The service door seems to be one of the most difficult parts of the body to keep in good working order. The trouble is usually in the door itself, although the manual operating mechanism may get out of order at times. On many buses the driver spends a good part of his time, often when he should be watching the road ahead of the moving vehicle, in trying to force a sticky door open or closed.

Doors should be at least 30 in. wide, although in practice they vary from 22 to 35 in. This can be compared with the exit-entrance of the one-man type of trolley-car, which is about 52 in. wide; but, as was said before, space is too valuable in the bus to provide a door that will carry two streams of passengers.

Seats in the bus should be arranged in accordance with traffic conditions rather than the design of the vehicle chassis. The latter sometimes has to control, however, as in the placing of longitudinal seats over the wheel-housings. The result is a well at the rear of the vehicle, which must be reached through the neck of the bottle formed by the central aisle. This well is sometimes needed, but it is often used when the space should be filled with seats. Fig. 10 shows seating layouts for city and suburban service.

The standard cross-seat is 15 in. wide and 32 or 34 in. long. The central aisle is from 14 to 24 in. wide. The 34-in. seat is the better, since the narrower seat will not in reality allow the use of wider aisles. At the same time it may be uncomfortable for two persons. The real aisle-clearance is between the hips and shoulders of the seated passengers. With the 15-in. width, seat centers should be at least 28½ in., which gives only about 11-in. knee-room. These seat centers should coincide with side-post centers.

Seat construction has settled down to the spring type for cushions; springs are sometimes, although rarely, used in the backs. A patented seat, which is said to have given satisfaction on a 30-passenger bus, is supported on two pedestals, each of which is a pneumatic cylinder or dashpot. This really amounts to a shock-absorber directly applied to each seat.

Seat covers are of rattan ordinarily, with plush or leather for de luxe designs. Rattan is low in first cost and can be kept clean more easily. It is somewhat slippery, but this can be taken care of by the seat design; by raising the cushion at the front and recessing the back slightly. This gives more knee-room and comfort, and tends to hold the passengers firmly in place, even over rough going.

Floor coverings of carpet or linoleum are found on some vehicles, but for wear and hard service the floor is slatted, in the aisles and between the seats. The slats can be attached to flat strips of steel, from which they can be removed when worn. This scheme, which has been used in England, is said to make cleaning easier also.

The driver's comfort is equally as important as passenger comfort, and is taken good care of in the new de-

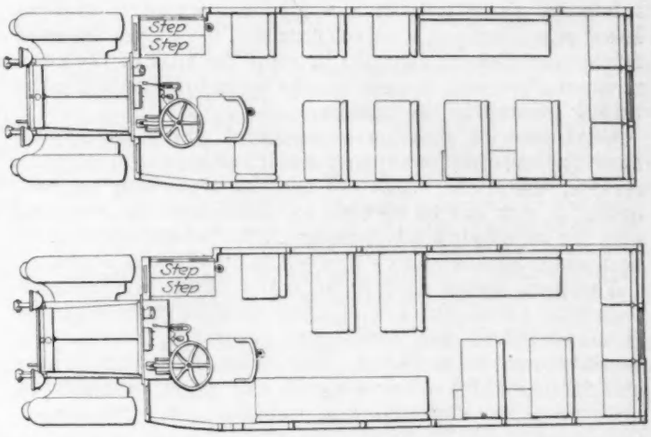

FIG. 10—SEATING LAYOUT OF A 20-PASSENGER BUS (ABOVE) FOR INTER-CITY SERVICE AND (BELOW) FOR CITY USE

signs. The seat is of bucket shape with good springs, and sometimes has an adjustment for height. A railing is placed so that passengers cannot crowd against the driver, wind and sun-shields are attached on the outside and a curtain or bulkhead prevents light from the rear being reflected on the wind-shield.

HEATING, LIGHTING AND VENTILATION

A heating system such as is shown in Fig. 11, using the exhaust gases from the engine, is installed on most buses put out within the last year or so. Previous to that, however, many buses carried small stoves during the winter months, which of course was unsafe and unsanitary. The first exhaust systems were makeshifts, with the gases led through pipes inside the body. While this was often effective, or at least provided satisfactory heating, it was a clumsy arrangement, hard to control and difficult to keep gas-tight. It was used, however, because operators claimed they could not get heaters of sufficient capacity, at least for large buses.

The problem seems to have been solved by the use of two heaters, placed close to the front of the body. The

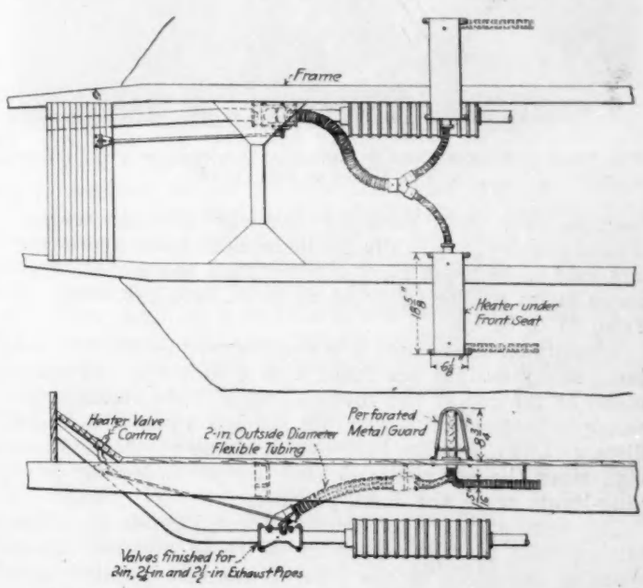
Frame
Heater under Front Seat
Heater Valve & Control
2-in Outside Diameter Flexible Tubing
Perforated Metal Guard
Valves finished for 2in, 2½in and 2½-in Exhaust Pipes

FIG. 11—INSTALLATION OF HEATERS IN A 25-PASSENGER BUS SHOWING CONNECTIONS OF FLEXIBLE TUBING AND VALVE CONTROL OPERATED BY THE DRIVER'S FOOT

inlets for these join in a single connection to the exhaust pipe, through a valve controlled by a lever inserted in the floor-boards near the driver. Because of the compact arrangement, no provision is made for insulating the tubing leading to the heaters.

Good interior lighting is essential where passengers have the evening newspaper habit, although in country service, where the buses are used at night only on Saturday, it may not be necessary. Good lighting is needed also for displaying advertising cards, which promise to be a considerable source of income to the bus operator.

The 2-cp. bulbs used in so many buses may help in collecting fares, but are of little service to passengers. It is recognized now that larger generating and battery capacity must be installed. The 300-watt generator system for the Fifth Avenue Coach Co. buses, although in some respects a special job, indicates that the larger equipment is available. The 12-volt battery system seems to have found a place, although the 6-volt design is used widely.

The present tendency is to mount dome reflectors on account of the low head-room. Prismatic and opal reflectors have been designed however for bus service. These require practically no more head-room space and are said to be much more efficient than the domes. The large buses are being fitted with six to eight bulbs, of from 21 to 32 cp.

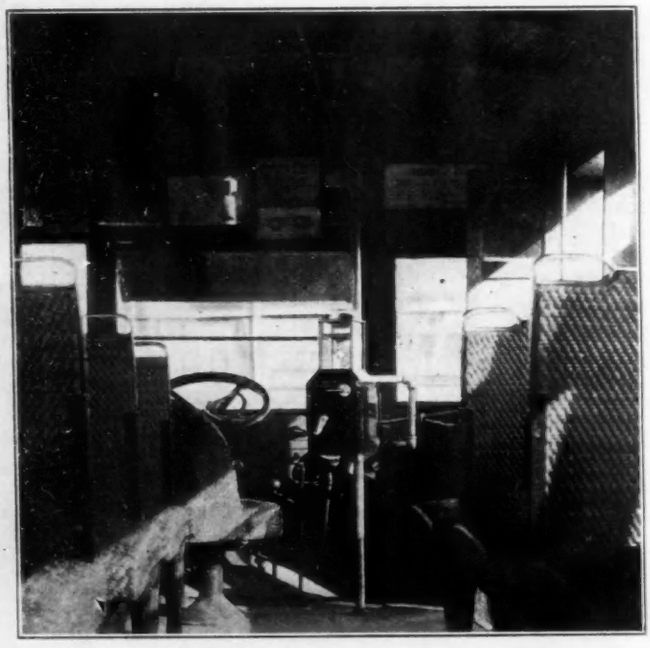

FIG. 12—REGISTERING TYPE OF FARE-BOX MOUNTED ON A STANCHION AT THE RIGHT OF THE DRIVER

Identification at night is a requirement peculiar to the bus. Many designs are fitted with a bulls-eye, of special color, at the top of the roof in front. This permits the would-be passenger to pick out the bus when it is some distance away, and the bulls-eye lights up the destination sign when the bus comes closer. Purple and green running-lights serve the same purpose.

Bus ventilation, in its simplest form, depends upon the service door for the admission of fresh air, and upon vents at the sides or the rear to exhaust polluted air. Most doors admit a slight amount of air even when closed, unless they overlap at the top and bottom, when they are practically draftproof. Air is admitted also through openings across the front of the body, above the driver.

The latest practice is to insert ventilators along the center of the roof, with a screen or grating in the ceiling. These ventilators may be automatic in operation, not requiring any adjustment; rain cannot enter but the air exit is always ready for service. Windows are being equipped with adjustable curtains and sash, safety catches, rubber weather-strips, anti-rattlers and upper stationary sash with Florentine glass. Wire grating or wood slats are placed outside to keep each passenger wholly inside the bus.

Pockets for windows are of two types. The overhead pocket requires good head-room, and heavy top construction with a higher center of gravity. Then there is the side-pocket type that takes up valuable space needed for seats and aisles. The overhead opening seems to be favored, undoubtedly because the windows are easier to handle.

FARE-COLLECTION DEVICES

The collection of fares, while more of a traffic than an equipment matter, is giving much trouble to bus operators. The necessity for simplicity and accuracy has led to the application of mechanical devices, such as illustrated in Fig. 12, to save work for the driver, insure his honesty and speed-up service.

A money-changer, fastened to the side of the bus or at some other convenient place, is the first step; next some type of fare-box, with perhaps an overhead register that the driver pulls to record fares. The latest arrangement is what may be described as an instantaneous registering lamp-post type of fare-collection device. This records each fare as deposited, and is driven by a flexible shaft connected to one of the accessories on the bus engine. The use of such a mechanism should make unnecessary the regulations that forbid the driver to collect fares while the vehicle is in motion.

STATE AND LOCAL REGULATIONS

Laws and ordinances by the hundred, almost by the thousand, have been passed to "supervise and regulate" the bus. The safety and comfort of the traveling public are protected by a host of these regulations, many of which are more honored in the breach than in the observance. In common with other users of motor vehicles, the bus operator is limited as to weight, dimensions and speeds. In addition, he often must pay special taxes that influence the type of equipment.

To assure safe operation, presumably, the carrying capacity of the bus is limited. In some States, in New Hampshire, for example, the manufacturer's rating is taken as the legal limit, and no standees are permitted. New Jersey allows 50 per cent of the seating capacity to be carried as standees. Connecticut allows two more than the number of seats provided. The District of Columbia permits one standing passenger for each 1.5 sq. ft. of floor area, this being calculated on the area remaining after deducting the space occupied by seats and 10-in. knee-room for longitudinal seats. In Maryland the maximum carrying-capacity is the total length of seats divided by 16, except when the result exceeds the carrying capacity. This method, in effect, bars out standees.

An emergency door that can be opened from the inside in case of accident is required in a number of localities. Other equipment insisted upon, for safety reasons, includes speedometers, inside lights, extra tires, skid chains, warning device, and a fire protection device.

The requirements for heating, lighting and ventilation are usually indefinite; when enforced they depend upon the interpretation of the authorities. Closed buses in the District of Columbia must have a minimum temperature of 40 deg. fahr. between November 1 and April 1. Interior lights, of 2 cp. or more, are demanded in Ohio and other States. In Maryland each bus must have two ventilators.

In many States the taxes are based upon seating capacity, and the larger vehicles pay more per seat than the smaller. Florida exacts from the buses used as common carriers a fee of $5 per seat for 7-passenger or less capacity, $7.50 per seat for 7 to 17-passenger capacity, and $10 per seat for more than 17-passenger capacity; in addition there is a tax of 75 cents per 100 lb. of gross weight of the vehicle and the load. Connecticut and Maryland also have systems whereby the fee shoots skyward for the larger buses.

The regulatory authorities may even supervise the purchase of equipment, approve drawings and specifications and compel the improvement of those already in service. It is too early yet to judge what the result of this supervision will be. At present it seems to make for better buses. With wise regulation, and with improved highways that will permit lighter vehicles and more economical operation, the bus, already with such a wonderful development, will have an even more wonderful future as an instrument of transportation not only on the streets of our cities but also in inter-city service.

THE DISCUSSION

R. E. PLIMPTON:—What I have tried to do in this paper is to bring out the transportation viewpoint, the viewpoint of the operator who is operating mainly the smaller lines. What I call here "the country bus" is really the small vehicle that often is operated over rough roads or in service where the traffic is light.

The conclusion of the paper refers to regulation very briefly, only as it affects the design of the vehicle, but that thing is coming more and more. President Bachman referred to the competitive feature, or possibilities of the bus, but I do not see any competition there at all. Mr. Green has referred to the bus as a public utility. I think that our institutions are firmly grounded on the regulation of public utilities and that the bus is coming more and more into that class. Already, more than half the States in this Country have some form of state regulation and, while they started in with restricting the lines and the fares charged, they will continue that and will get more into equipment, not only for safety, but for the comfort of the passengers; and, as that goes on, I think engineers and builders ought to keep more closely in touch with the regulatory authorities, so that they really will be informed. At present, the State authorities are taking many steps connected with design that they are sorry for when they realize what the steps mean. They require certain types of body, or certain types of tire, perhaps, and then, after they pass the law or the regulation they find out that it will not work, and that is not a good thing for anybody.

To show what some of the smaller operators are up against when they go into the business and also to show the viewpoint of a small city, I will read an extract from a Newburgh, N. Y., newspaper. They have about 50 buses now in Newburgh. Outside of New York City, I suppose it is one of the largest centers of bus operation in New York State, in spite of the fact that it is a comparatively small city. The city lies on the Hudson, so that one side of the territory is cut off; but, in spite of this, they have all this bus operation. This newspaper says:

> Any one contemplating going into the bus-transportation business will do well to figure the ultimate cost before going just far enough to have to turn back with a loss on his hands. First, there is a cost of one bus, which may be anywhere from $1,000 to $10,000. There is required a liability bond of $10,000, which costs $592. In addition, there is a New York State license fee, which costs $67.50. There is also a Federal license fee of $20, and $225 for property insurance on the bus. Thus it will be seen that it will cost, exclusive of the price of the bus, $904.50 before a fare has been collected, to embark in the bus business. The bus-transportation business is no plaything for men who have any regard for their money. The day when a man could run a tumble-down car in and out of Newburgh and call it a bus because no one cared enough about what he called it to put up a kick is probably gone forever. A man involved in the bus business in this section is regarded as a transportation unit and that line of industry is evidently not to be meddled with by those not knowing what they are about. If you can afford it, there is money in the bus-transportation line. If you cannot afford it, there is not.

Chairman C. F. Scott, of the Meetings Committee, told me some time ago that he took it as a matter of fact that practically every city and town in this Country had some form of bus transportation. I am inclined to amend that by saying that practically every city and town has had experience with bus operation, which is a different thing, because the dead bus lines mount up into considerable numbers. Of course, that applies in the city also. I think the reason for that is not altogether due, although it is partly due, to inadequate design of the vehicles; it is due also to a lack of transportation knowledge on the part of the operators. It is only a matter of time before they will acquire that knowledge as a result of these failures.

MERRILL C. HORINE:—Does not the second item in Table 1 of Mr. Plimpton's paper, the approximate entrance-height in inches, really mean the floor height above the ground? The Mack engine bore is 4¼ in., and the front axle is of I-beam construction. If he means by entrance height the height of the floor at the entrance, that will make it clearer; but by entrance height I should say is meant the first step, which of course cannot be as high as shown.

G. A. GREEN:—Referring to Mr. Plimpton's remarks in regard to the possible future employment of six-cylinder bus engines and six-wheel buses, our theory is to concentrate on the reduction rather than on the addition of parts. As to the six-cylinder engine, for normal bus operation in the average American city, we believe a four-cylinder engine of about 300-cu. in. capacity is adequate; and assuming proper design, speed and load variations can be taken care of by carbureter adjustments or gear-ratio modifications. If this assumption is correct, then certainly it is folly to add two more cylinders, thus increasing first cost, weight, number of parts and fuel bills. Of course, these remarks apply regardless as to whether the engine design is poppet or sleeve valve. But it should be pointed out that the much desired silence and smoothness of operation are comparatively easily achieved with four-cylinder engines of the sleeve-valve type.

In regard to the six-wheel bus, here again there are additional parts and, in all probability, additional weight and cost. In our judgment the value of this construction has not been proved. In short, it would seem a more logical plan to concentrate our energy on the improve-

ment of the four-wheel system that has given and is giving an exceedingly good account of itself, rather than expend any great amount of time and money on the development of a theory that in our opinion has not yet emerged from its early experimental stages.

In Mr. Plimpton's paper, a suggestion is made in regard to painting buses different colors for different routes. From our viewpoint this would be unwise, for with a public utility there should be the fewest possible restrictions placed on vehicles. The underlying thought is that any vehicle should be capable of operation by any driver on any route at any time.

GEORGE W. CRAVENS:—I think this whole matter comes back to the principle stated by Mr. Green; first, know your business, and then design something suitable to your purpose.

I am interested in several companies, among which is one that is experimenting with and will bring out a steam bus. There is no doubt that there is much to be said in favor of steam from the standpoint of acceleration and smooth operation, but I will not take time for that. However, in this bus-transportation problem you have a similar problem to that of the street-railway man in the last analysis. You must take care of your traffic at the least cost per passenger-mile.

In our investigation of motorbus requirements it seemed to us that standardization of body sizes and wheelbase boils down to approximately 25, 40, and 55 passengers as being good standard sizes. How nearly does that agree with Mr. Green's and Mr. Plimpton's determinations?

Secondly, I believe the time has come when it is necessary to clarify the bus situation. That has been done in the passenger-car and to a certain extent in the truck and tractor fields. It is time for a company to go into the business of building a vehicle from the ground up that will be consistent as well as suitable for its purposes. The time of makeshifts and of trying to redesign something you have to fit a new condition you know nothing about has passed. I believe that eventually some company similar to the Fifth Avenue Coach Co. will go into the business of constructing buses for sale that will be built along standard lines, and you will take them or go without them, the same as is now necessary when we buy a truck or a passenger car.

MR. GREEN:—We have analyzed the seating-capacity situation as nearly as we can, and as a result of our analysis we are building vehicles carrying, with the single-deck bus, from 25 to 29 passengers, and with the double deck, from 50 to 55 passengers. Undoubtedly there are fields for other vehicles, but we think the largest field is for buses of these capacities. Of course, there is also a field for the so-called speed wagon, seating around 15 passengers, but with vehicles of this character, the driver's wages consume a large proportion of the revenue, so the natural tendency will be to increase the seating capacity gradually to make up for this.

CHAIRMAN B. B. BACHMAN:—I used the term "speed-wagon" in the way that it has been used in advertising literature, to describe the vehicle of 1500-lb. and under carrying capacity that is used for general-utility delivery-purposes, rather than for passenger transportation.

HORACE L. HOWELL:—With reference to the question as to the proper seating capacity of a bus, I should consider that it would depend chiefly upon the character and class of service; that is, if it were a high-speed proposition, the single-deck high-speed type of bus would be the answer, with a seating capacity similar to that of the Fifth Avenue Coach Co., 25 or 29. Should the bus be required for urban transport service at slow speeds, a double-deck structure would seem more proper if the overhead clearances would allow it. In this case the number of riders would govern the seating capacity.

The first successful type of bus used by the London General Omnibus Co., London, England, was known as the B-type bus. It had a seating capacity of 34 passengers. That bus was used for a number of years and approximately 1000 of them were commandeered by the British Government for transport service in France during the recent war. A number of them are in operation today; but, owing to the growth in the riding habit and the consequent depletion of the fleet, the construction program of the London General Omnibus Co. called for a larger vehicle with a greater seating capacity. The company therefore established a program for its future operations, to meet the increased riding habit, by constructing the K-type bus having a seating capacity of 46 passengers and, later, the S-type bus having a seating capacity of 54 passengers. The operating statistics of the company show that the cost of operation for the larger passenger-carrying vehicle is not much more than it was with the B-type bus and it may be expected that, on account of the added seating-capacity and because of the comparatively small difference in operating costs, the consequent operations will be much more successful from a financial standpoint.

CORNELIUS T. MYERS: — In reference to capacity, it would seem that wherever bus lines have become established and their patronage grows, the larger seating-capacities can be employed profitably. In a great many districts very likely we find that the smaller bus will be the first installation, not only on account of first cost but because the regular service cannot be given as traffic has not been developed.

MR. PLIMPTON:—One of the most encouraging things in connection with the whole bus situation is that there are several companies now specializing in the construction of vehicles to be used as buses. We must bear in mind that although the traffic is light there is a great volume of other work done by the operator of the country bus. He very often carries light packages and freight; he may deliver milk or newspapers or do errands for people; and he usually has some other business. But for the territory he serves he performs a real service. In Italy and France this has been recognized and Government subsidies have been applied to this "country service," just to keep the buses going.

In connection with Mr. Horine's query, what I had in mind was not the step-height, but the approximate floor-height; that varies somewhat, but that is what the figures were intended to cover.

Mr. Cravens suggests three sizes of bus for standardization, the smallest being of 25-passenger capacity. Undoubtedly, there is a considerable field for a smaller vehicle of say 16 to 18-passenger capacity, and it should be given due consideration.

Discussion of Papers at the Chicago Service Meeting

THE discussion of the papers presented at the Chicago Service Meeting included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum amount of effort.

In addition to discussion given below, the discussion of the paper by J. F. Page entitled The Car-Owner versus the Service-Man, is printed elsewhere in this issue of THE JOURNAL, following the paper itself.

A SERVICE-MAN'S CRITICAL ESTIMATE OF AUTOMOTIVE ENGINEERING

BY B. M. IKERT

AFTER generalizing on the need for greater consideration in automobile design for service and maintenance requirements, the author discusses the accessibility of car parts at some length with the idea of pointing out difficulties encountered by service-station mechanics when parts are inaccessible, this having a bearing also on the length of time required for repair work and the consequent increased cost to the car owner.

Specific instances are given and illustrated in which improvements in design could be made to obviate trouble. These are inclusive of cylinders, cylinder blocks, pistons, bolts, cap-screws, nuts, valves, dashboard instruments and general take-up adjustment. Special emphasis is placed upon certain inaccessible parts that necessitate excessive dismantling.—[Printed in the April 1922 issue of THE JOURNAL.]

THE DISCUSSION

PRESIDENT B. B. BACHMAN:—There has not been the proper contact between the man who designs, the man who builds, the man who sells, the man who maintains or services, and the man who uses the motor vehicle. Reasoning from ordinary human affairs, such contact as there is and such influence as is brought to bear will have their greatest weight dependent upon the aggressiveness of the contender. The man who is closest to the designer is the man who is building, usually, and the man that is almost as close, particularly in the present-day markets, is the man who is selling. The man who is servicing is not so close, and the man who is using is considerably farther away. The man who is building has fairly complete access to the designer, and the man who is selling gets contact with the man who is designing with a reasonable degree of facility. The service-man is farther away, but he does know the individual who is responsible for designing. Mr. Ikert's paper deals largely with passenger-car operation. I am interested more particularly in the transportation of merchandise, but the underlying fundamental principles are the same. The man who is using should remember that he ought to have direct access to the man who is designing, through the service-man and the salesman.

All design work is a matter of compromise. I believe the machine has never existed and I doubt whether it ever will exist that is perfect from any one standpoint. It will be effective from a theoretical viewpoint in some one particular or other; from a production viewpoint for some theoretical reason, from a selling standpoint for theoretical and production reasons, and from a service standpoint from some of the other reasons. The man who is designing must take all these various elements, bring them together and study each individual item. Because some designers have not had a proper conception of the relative values of these different items, there has been a predominant influence in their work, due to the fact that some of these factors have brought a greater influence to bear on the designer than some of the others. If the designer could spare time enough from his other duties to canvass the Country, come into contact with the men on the firing-line and get their viewpoints, I believe more progress would have been made along these other lines. We believe that we can effect a contact between the user and the manufacturer, grouping with the manufacturer the designer and the producer, so that these fundamental problems will be in evidence and the designer will get a picture of some of the practical things that have not had much consideration.

Mr. Ikert mentioned the aging of cylinder blocks. It seems to me that this is not so much a service as a production problem. It has a bearing on service matters, as he outlined, but fundamentally, it seems to me, there are many factors of design that enter into it which vary the requirements. At a recent meeting the aging of cylinder blocks for 12 to 18 months was discussed. There probably is a considerable division of opinion as to what is the best method but from the production standpoint we must recognize that it is not good business to put into an automobile a casting that has been expensively reduced to good form and then, due to changing temperature conditions, have it leave that form in a radical degree.

There is room for considerable improvement in the matter of wiring systems from the motor-truck standpoint, along the lines of electrical application. The suggestions that Mr. Ikert made with regard to the standardization of wire colors seem to me to be well worth considering.

Mr. Ikert indicated a thought with regard to the so-called service engineer, one phase of which I wish to emphasize, in connection with the relation of the service-

man and the engineer. I believe that it is not necessary for the man doing service work to tell the engineer the trouble and how to fix it. That is one of the things that has held back the development of design from a service standpoint. The man doing service work has difficulty enough to fix troubles, and I believe that he is not usually possessed of the necessary qualifications to enable him to analyze, and to suggest remedies. It seems to me that this is fundamentally a part of the engineer's job. If a man comes to him with an honest criticism of something that is wrong, the engineer ought to be able to find a remedy for it.

A. H. PACKER:—Several years ago I was with a large electrical company on the service end of ignition, starting and lighting equipment, and later I was in its engineering department. In the engineering department, although rated as an engineer, I had the standpoint of the service-man. In the discussions I took one side of the argument and the other engineers took the other side. To illustrate, in laying out an ignition outfit, it was my suggestion that the cams be made in a certain way, which was an easy one, so that the ignition unit could be changed from a right-hand to a left-hand unit, but I was overruled. I was sent to install the first sample equipment. The engineering department's instructions called for a right-hand unit, which was sent, but I found at the factory that a left-hand unit was necessary, showing that the more universal a piece of apparatus can be made, the more likely it is to suit the engine for which it is intended. That may not come up after getting into production but, on other hand, the service-station would need to carry two types of cam in stock instead of one, for each size of engine; four, six and eight-cylinder right-hand and left-hand rotation parts would be necessary. Such difficulties are due to a lack of understanding of the service-man's problem, and a lack of appreciation of how serious it is. Another recent illustration is that of a designer for a large electrical company. He designed a generator and the test was absolutely satisfactory; but when the generator was put out into service, complaints began to come in. A practical mechanical difficulty had developed which nullified all the fine electrical design. If the designer had had an open mind. he would have gone into the field and got pointers from the service-man. Not having the service-man's viewpoint, he had no constructive ideas to remedy the defect. The result was that the company's reputation suffered because of an incidental feature that entirely discounted the advantage of the good engineering.

R. B. MAY:—There are a few relatively simple ways to get such information as has been suggested. Any service manager of a motor-car company or a manufacturing plant knows what parts are used in repairs and maintenance work; but has any analysis ever been made to ascertain the proportion of expense on such repairs between the value of the repair parts and the labor put upon them? When new apparatus is designed, if a time study were made in each manufacturing plant of each repair operation, one would know what the expense of ordinary repairs would be, and be able also to instruct dealers and service-men as to the best way to accomplish those repairs. We have had to do that in our own work. We find that it is possible to cut down the time for repairs to about 25 per cent of the ordinary time, when an accurate and detailed study has been made. That information could be distributed by each manufacturer as a part of his service to his various dealers. In that way the time for repairs could be cut down materially.

It has been estimated that car dealers change every 2 to 2½ years, which means that the bulk of service work on cars over 2 years old is done in independent garages that are not informed by car and accessory manufacturers at present of the best methods of maintaining the cars and the apparatus. The demand for such information is shown by the manuals that are sold at exorbitant prices. For instance, along electrical-accessory lines, one manual that simply takes the place of a manual that could be prepared by manufacturers sells for about $25.

J. C. GOREY:—For the past 10 years I have been engaged directly in handling assembled clutches, transmissions, universal-joints and axles that are used in assembled cars and trucks. The engineering departments at the factories are overburdened with questions daily. If the man who is in the field to repair and remodel different units would stop and consider the wonderful growth of this industry, he would try to remedy some of the troubles and lessen the number of complaints with which he is annoying the engineering department.

I am often asked questions. For instance, a man asked me how to obtain two beveled bushings for a certain car. I told him to go to the company that handles the same model of car. He wondered why the man from whom he purchased the car did not tell him that. We are wrong when we have not furnished the owner of the car with such information. We are afraid to tell him direct that another make of car has the same unit in it. He will find it out eventually and will ask why he was not told it in the first place. All there is to this whole thing is contact with the owner of the vehicle. We should tell him that he can get this part or that part where he pleases. Let the engineer fathom the greatest trouble and let everybody else do his part.

J. WHYTE:—In regard to the use of colored wires for the electric wiring, I have been developing a component part of a car that includes the electrical equipment as a standardized unit. We were very anxious that all the wiring in that equipment should be easily traceable from one end to the other, and decided to use different colored insulation for the wires. We desire also that the coloring should correspond with that used by the chassis manufacturers and made a survey as to how many manufacturers were using wires having insulation of different colors. We find that there are no two makes of car in which the same colors of insulation are used for any given specific purpose. We, therefore, had to standardize on a group of colors for our own work. I think that we ought to have a recommended practice on the colors of insulation to be used for the various electrical circuits in motor vehicles.

There is not a chassis manufacturer that I can recall who does not protect a wire with either metallic conduit or circular loom, and it is a physical impossibility without making a test on every circuit to find out where the other end of the wire belongs. The only drawback that I can see to using insulation of different colors is the fact that there are some different circuits that use the same size of wire. For instance, on the average car, we probably have seven circuits using No. 14 or No. 12 wire and, if the total wiring requirements are divided into seven parts, some purchasing agent will find out that if he buys it all with one color of insulation he can save money and the engineering department will be immediately overruled. In the past, much of this kind of trouble has been caused by purchasing departments in saving small sums in such ways.

Another trouble with regard to service on any component part or on any car is that there is not, in my ex-

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perience, full co-operation between service and engineering. In designing a new unit, after we had it completed we tried to get in touch with every service-man we could find, realizing that the ultimate consumer is our best advertiser. We invited those men to come in, go over our unit and give us their criticisms. It meant some radical design changes to conform with some of the ideas and criticisms that we obtained. We have been surprised to find that a unit that meets the ideal of a service-man is the cheapest to produce. In other words, a unit that is economical from the service standpoint is also economical from a production standpoint; any part that is easy to dismantle and replace is easy to build in the first place.

Many car engineers neglect to figure service into the cost of production. The average car-factory does not get the full price for all of its service parts. The manufacturer must make concessions to keep the large distributors, dealers and owners satisfied. How many car companies have ever calculated the annual cost of such concessions and added that to the production cost of the vehicle? In many cases this cost would offset some of the economies that they think they have made by cheeseparing in the initial stages.

In regard to the use of service records and the improvement of design, the service departments of a few car-companies send a daily digest of major troubles to the engineering department. I know of engineering departments where these are carefully filed, but that is all that is ever done with them. If these digests were analyzed by some competent assistant in the engineering department, they would form a fine volume of data for refinements and improvements that should go into car design from year to year. Such a record can be obtained in no other way than from the performance of the car in the hands of the actual owner. The average owner mistreats his car. Cars that will perform through their engineering and development periods with absolutely no trouble, show some of the most weird performances when they get into the hands of the average owner. A digest of those troubles is invaluable in the engineering department if it is properly used.

CHARLES M. MANLY:—In my address at the 1919 Annual Meeting, I made a prediction, that I think is working out all right, to the effect that inside of 10 years we would have as many engineers working on the operating end of automotive work as we at that time had working on the designing and constructing end. Mr. Ikert's paper is very timely and should create much interest. I think that we are rapidly approaching the condition where we will have many more engineers in the operating end than we have had heretofore, due to several causes. First, the demand for designers is not so great now as it was a short time ago, and some of the designing men naturally will work over toward the operating end. But I think the biggest factor in the demand for operating engineers is that, especially in connection with merchandise transportation, the operating companies will have their own transportation engineers and require that the design of the vehicles be such that most of these minor service troubles will be eliminated. There will be more and more demand for the transportation engineer, and therefore there will be more and more demand for this interconnecting link that Mr. Ikert has mentioned who will bring home to the designers the necessity for meeting the sales situation, especially with the companies maintaining transportation engineers.

The matter of using different colors for the insulation of the wiring is of considerable interest to me. During the war the use of different colored insulation for the wires of the electrical equipment and different colored pipes for the gasoline and oil and other systems on airplane work was considered, and we tried to do some standardizing in this regard. The Navy had a system in use on the ships in the grand fleet in which certain colors meant certain things, but it appeared to be impossible for them to consider anything that was not patterned after the plan that was used in connection with the grand fleet. There were some other interests that believed other considerations were equally important. I believe the British Navy had a different system from the one that was in use in the American Navy. We were just commencing to get the matter pretty well straightened out when the armistice came. I think nothing further has been done on the subject since that time.

A. D. T. LIBBY:—I attended a recent meeting of the executive committee of the Automotive Electrical Association. One of the points brought up for discussion was, what we are to put up to our engineers to work out in the way of standards. The association, which comprises substantially all of the starting, lighting and ignition-battery manufacturers, is trying to promote the use of the S.A.E. Standards to the greatest possible extent. I have heard discussion as to the value of S.A.E. Standards, and their value was set forth in the December 1921 issue of THE JOURNAL; but everybody questions how much these electrical standards are used. The Automotive Electrical Association men who sell the equipment propose to get standards that they can sell. If they cannot sell standards, they want to find out why and then they want to get the present standards changed so that they can sell them. Many members of the committee of the Automotive Electrical Association are also members of the Electrical Equipment Division of the Society's Standards Committee.

As to referring the matter of wiring to the Electrical Equipment Division, I am very much interested because of having been its chairman in 1921. It was mentioned that resistance would be offered by the purchasing departments. Probably some resistance will be encountered also from the factory, because the production departments no doubt will object to handling several different colors of wire. If they handle only one reel, they can pull that wire out, chop it off, make up a cable and install it in the car; but if they must have five reels and pull off five different colors, they are likely to object. However that may be, more attention must be paid to what is put into a car from the service standpoint, and to what takes place after the car gets out into the hands of the user.

This Automotive Electrical Association has a Service-Men's Committee. This committee is wrestling with the very problems that we are discussing. What is service? How are we to take care of it? How is service to be paid for? Will service be absorbed by the service-men or will it be turned back to the factory? All those questions are vital and difficult to answer. Many of the questions that arise in connection with service must be answered in each individual case. One cannot say where the charge will fall. In addition to the committee I have just mentioned, an association known as the National Electric Service-Men's Association has been formed. It is holding a meeting here in Chicago at present to discuss the same problems we have before us here today.

Service, as outlined in Mr. Ikert's paper, should be the subject of future papers during the coming year. Nothing is more important than the service given car equipment. The design of the engine, the carbureter, the magneto and the ignition unit are secondary to the manner of their installation in the car. The illustrations in

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Mr. Ikert's paper are very apt and show the difficulties that are brought about by improper installation. After the engine and the other units are designed, when they are put into the chassis they may not fit and may be inaccessible. In one car in particular the magneto was connected with the generator so that the breaker-box of the magneto was within ½ in. of the rear leg of the engine and it was impossible to get at the breaker-box without dismounting the entire generator and magneto. Just such points as this can be overcome by proper cooperation between the designing engineer and the man on the outside. I have in mind another car that, to my mind, is ahead of any other car in regard to the accessibility of its units. The engineers of that car are to be congratulated on the thought that they have given to placing the car units so that they can be gotten at by the servicemen when the car gets out into operation and is sent to them for repairs.

PRESIDENT BACHMAN:—We are certainly very much gratified to hear from Mr. Libby that the organization he mentions will promote the work of the Standards Committee. It is this kind of cooperation that we are working and hoping for from all the commercial organizations and, on our part, we want to deserve it.

C. D. HOLMES:—This problem of inaccessibility is one that I have been "getting at" for years, particularly in regard to the proper construction of engines for truck service; for in truck service delay for upkeep and repair runs into money faster than anywhere else. A truck should be kept moving constantly, as every hour's delay means a heavy loss. It may be of interest to know that the word "Get-at-able" was trade-marked more than 10 years ago because, at the time, I believed that sooner or later the public would tire of paying out so much of its good money for the taking down and setting up again of an engine to make a simple repair. Further, the taking down and setting up is often done carelessly, particularly as to replacing gaskets, with the result that new troubles are started altogether too soon. An engine should never be taken down or taken apart in any way if this can possibly be avoided, for it may be weeks before the engine will run properly again. All this is because the construction or housing of the engine is such that, in case of trouble on the road, the part to be repaired or adjusted is usually so inaccessible that a wrecker has to be called, the truck towed in, and the engine taken apart before the truck can be put on the road again. Had the construction been different, the repair or adjustment could have been made on the spot, and the truck could have proceeded under its own power with but short delay. Measured in money, this means about $50 in the one case as compared with $1 in the other. If this appears to be an exaggeration, figure a supposable case in which a heavily loaded truck that is only 5 miles out on the road has engine trouble and must be towed in by a wrecker. The repair cost is but one item, for the entire cost includes that of towing, loss of time on the road and the time of at least two men who wait around.

If any such saving as this can be made in upkeep and repairs through accessibility that permits getting directly at every part, why has this not been done before? This is a natural question, although one that I shall not undertake to answer here, but the facts are evident and the remedy can be applied. Instead, we have undertaken about everything else connected with the engine and have experimented with the carbureter, the manifold, the ignition and the like. Many papers have been written on these various subjects, but the sum total of all such improvements works out to a saving that is small compared to what might be effected if the engine were only made accessible and simpler. This might be done and is certain to be done soon, if public demands are heeded.

The construction that I have in mind would cost but little, if any, more than the type now in general use. The efficiency of the engine would in no way be impaired; rather, it would be improved. The weight would be less. In looks, it would be simplicity itself. On one side there would be no attachments whatever; on the other side which, for safety in working, would be the side away from the road, there would be only the necessary carbureter, generator, starter, magneto and pump, all built into and forming a part of the housing. Yet these parts would all be removable separately, all of the oiling parts also being reached easily from the side and not from underneath.

In an address[1] at the 1921 banquet of the Society in New York, we were told by R. E. M. Cowie, vice-president of the American Railway Express Co., that "the motor vehicle is a wonderful machine, but it is too complicated," and that "the cost of upkeep of the average motor-vehicle makes the average man stagger." His advice was to simplify everything. He said, "The simpler the machines are, the more efficient they are, the less liable to trouble, and the more economical in operation and upkeep." These statements go to prove my point, and to make clear that this is the cloud on the horizon that threatens the very life of the industry. Yet we have gone on as before, presumably because no one dares to pioneer a new style of engine construction that is solely for the benefit of the user. The engineers of one of the large commercial organizations had it figured out that, with engines all of the type referred to, there would result a very great saving in upkeep, because delay in this case ran into money very fast and the aim was to keep moving at any cost.

In the United States Coast Guard Service, where life is at stake, the only engine they would consider was built so get-at-able that even the crankshaft could be taken out through the side, and any piston or crank-box could be changed in a short time. In fact, it is a matter of record that rescue work was performed while a piston was out of the engine. Had it been impossible to remove this piston when the trouble occurred, the boat would have been helpless and life would have been sacrificed. Everything possible is done to make the engine perform under the most adverse conditions. With spare parts on hand, they can meet almost any emergency, owing to the exceptional accessibility of the engine. This only goes to show that, where necessity is the master, we can accomplish things that under other circumstances might seem impossible. The Coast Guard Service is certainly the hardest of any on the powerplant. We can take a lesson from what it has done and build our truck powerplants so that the user will not be obliged to pay out money unnecessarily for upkeep and repairs, owing to inaccessibility.

How often it is the case that the really big thing that we are looking for is right before our eyes, but we go traveling around and around unable to see it. I am convinced now, more than ever, that I can show greater economy of operation, with the average driver, with an engine that is get-at-able in the sense to which I refer, with no other particular qualification except oversized bearings, than can be shown with any inaccessible engine that has all the very latest improvements. We fail to realize how a driver can upset our theoretical economies

[1] See THE JOURNAL, March, 1921, p. 249.

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by careless and poor regulation but, given spare parts and an easy way to use them, it would be a strange man indeed who would not help himself. At least, a man can be forced to do so, or to show good and sufficient reason why he does not. This can be controlled largely if the engine is sufficiently accessible, but no one has yet been able to devise ways for making a careless driver keep his regulator set to the best advantage. So long as regulations are necessary, this will always be true. Hence, I say that simplicity and "get-at-ability" mean greater economy of operation than anything else.

HOWARD CAMPBELL:—One of the peculiarities of the American people is their knack of isolating some one word of our fast-developing "American" language, and using it for every legitimate and illegitimate purpose until it is worn to a frazzle. The indiscriminate use of the words "efficiency," "camouflage" and "sell" shows what may happen to an otherwise perfectly good word when the public fastens upon it in this way. In connection with the servicing of automotive units the word "service," which has always covered a multitude of sins, is becoming more and more indefinite and, unless something is done to rescue it before it is too late, it will have lost its original meaning and some other word will need to be devised or provided to fill the place for which this word was intended.

The purchaser of an automotive unit buys his car, truck or tractor, as the case may be, with a vague understanding that his purchase entitles him to something that is known as "service." In an effort to make this service effective, the various companies have organized service departments. Most of them seem to look upon the service departments as necessary evils, and that is as far as their interest goes. It is true that some manufacturers have their own distributing stations, and customers are supposed to come there for the necessary repairs. Such manufacturers usually have at least one man in the repair-shop who has been through the factory service-school and is assumed to be capable of doing any job required in what is supposed to be a standardized manner. But, even then, the likelihood is that this man must do the job with tools that he or the service-manager has devised, with the result that the job may or may not be done correctly and in a reasonable length of time, so that it is approximately in the condition in which it was turned out of the factory. I understand that the manufacturer of what is probably the most popular car in the world requires only that the dealer or service-station manager purchase car parts from the factory, and keep his prices within a certain limit, to obtain the right to use a sign that reads "Authorized Service-Station." So far as I have been able to learn, all that the manufacturer authorizes is the use of the car parts. The service-station manager can use any kind of machinery that he likes or any kind of tools that he has or may devise, and can turn out the work in whatever length of time he requires. Of course, the price factor limits the time to a certain extent; but it has nothing to do with the quality and, so far as I can learn, this is the only automobile firm in existence that attempts to regulate the prices charged.

It should be obvious, even to the most casual observer, that a job done with poor tools will require a much longer time than the same job done with tools designed for the express purpose. Further, good work cannot be done with poor tools. So, under the present system, where each service-station manager or garage foreman buys only such tools as he must have and cannot make, and manufactures all of the others out of such material as he has at hand, it is obvious that "service," as exemplified by a dozen service-stations, is very likely to mean a dozen different things.

I think there is no question that the largest automotive service-stations in the world are on Long Island, New York. Long Island City is just across the East River, within a few minutes' travel from "Automobile Row" on upper Broadway, New York City, and it is easily accessible, yet out of the crowded section. The service plants there include those of the Packard Motor Car Co., Pierce-Arrow Co., the White Motor Co., the Rolls-Royce Co. and several others, including the Hellman Motor Co., which is an "authorized" station. The New York Telephone Co. has its own service plant there and it is by far the most complete. This company owns more than 1000 motor cars and trucks, including nearly 700 Fords.

In the summer of 1921 I spent some time in each of these service plants, gathering material for a series of articles that have since been published in the periodical with which I am connected. I had an opportunity to observe the manner in which different organizations went about the matter of repairing motor cars and trucks. I discovered, among other things, that not only did these different service-managers employ different tools and methods for performing approximately the same operation, but that different kinds of tools and methods were employed for performing the same repair operation on the same kind of car or truck. Five different service plants had five different methods of align-reaming the main bearings. They all had different ideas and tools for reaming and facing connecting-rods, and one plant had two different kinds of fixtures for performing this operation. Practically all these pieces of equipment were designed by the shop foreman or superintendent, and were made in their own shops. One plant uses an electric hoist on an overhead trolley to lift an engine from the chassis, another uses a chain hoist and a third uses a floor crane operated by a crank. One plant uses a certain kind of reamer for reboring the cylinder blocks, another uses a different kind, a third uses a patent cylinder-reboring tool and yet another grinds the bores. The chances are that four different car-owners would be charged four widely different prices for having approximately the same kind of job done.

The New York Telephone Co. does not hesitate to make any equipment necessary to keep its cars and trucks in operation. It services its own units. This is considerably different from servicing the machine of a customer who will pay whatever the bill amounts to with little, if any, protest. Consequently this company has tools for removing bearing-caps, pulling out camshafts, removing clutches from their shafts, removing drive-shaft sleeves from Ford engines, holding bearings while reaming, compressing the packing in a rear-bearing case, testing magnetos and doing all kinds of jobs that without special equipment would require much more time than the company thinks is necessary. It makes every piece of equipment that is required to expedite the repairs, whether it be a tool, jig, or templet, and the service-plant manager claims that they save enough in every instance to pay for the tool many times over. Those of our factory service-managers who are looking for ideas would undoubtedly find some good ones there.

Some years ago the designers of a certain well-known make of car included a steering-gear in which no provision was made for taking up the wear. In due time numbers of these cars began to appear in the service-station to have the steering-gear repaired. Some one there devised a method of repairing this part so that it was practically as good as new and so that any future

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wear could be taken up without much trouble. But I doubt if any of the others of this company's service plants know how to do this, or whether the home plant ever heard of the idea. Suppose that the owner of one of these cars were to take it into this service-station to have the play in the steering-gear taken up. He would have his car back in a reasonably short time, pay a reasonable price for the job, and probably would feel perfectly satisfied. Suppose another man who owned the same kind of car took his car into another service plant for the same purpose. The chances are that they would either make him buy a new steering-gear, or give him a job that would wear loose again in a short time. If it should happen so that those two men met and compared their experience, one can imagine that the latter man would be very angry.

The foreman in the machine shop of the Long Island service plant of the New York distributors of another well-known make of car has devised a method of testing valve-springs so that he knows that every spring used is of the proper tension. The fact that he finds some weak springs shows that such an operation is necessary. But I doubt that all the others of this company's distributors have similar testing devices. The same foreman invented a gage for testing the grinding of valve-heads. The gage is bell-shaped, having a hole down through the handle for the valve-stem, and the inside of the bell is ground to the exact angle that the valve-seat was intended to have. The gage is made of tool steel, hardened and ground. The grinding operator grinds the angle of a valve until he has a seat, then he puts a bit of Prussian blue in the bell of the gage and rubs it around. Then he inserts the valve and turns it around in the gage while the valve-seat rubs against the Prussian blue. An examination of the seat will show whether the angle is perfect and whether it is seating all the way around or not. If the seat is not perfect, he changes the set-up of the machine until the desired results are obtained. Such accuracy as is obtained by this means would not be possible by the use of the ordinary bevel protractor such as the average machinist uses, and certainly the job would take much more time if the operator had to try the valves in a cylinder block. Why does this company not furnish each one of its service plants with one of these gages?

Contrast the methods in use in these service plants, which are supposed to be the best in the world, with the methods in use in the factories in which the cars were made. Practically all of the nine service-plants that I visited were operated by manufacturers who pride themselves that the methods in use in their factories are the best that can be obtained or devised. Their manufacturing methods, their tools, their gages and their inspection methods are standardized. Everything in their shops that can be standardized is standardized, so that all parts will be alike and every car turned out just exactly like every other one. But when the man who has bought one of these cars needs some repair work done, he finds that one shop gives him one kind of a job, that he gets the car back in 3 days, and that it costs him, say, $45. He finds also that another shop gives him another kind of a job, that he gets the car back in 6 hr., and that they charge him $12. The worst of it is that the shop where he got the poorest job and paid the most money may be the distributor's own service-station.

I was told recently of a new manager who was sent to a certain Western city to take charge of a sales and service organization for the makers of a very prominent high-grade car. After he had been there for some time he discovered that the amount of service work done by his establishment was comparatively small and, upon looking up the records of owners in his district, found that very few of them ever came near his place. He walked down the street until he located a car of the brand that he was dispensing, broached the subject of service to the owner and asked him where he had his repair work done. The car-owner replied to the effect that the local service-station did not have the proper equipment to do a decent job, that it took them about three times too long to do a job and that when the job was done, it was not satisfactory. This manager returned to his own service-station and looked it over. He found that the machine-shop equipment consisted of two vises, one of which was broken, a post drilling-machine and an arbor press. It is strange that the company was even able to sell any cars in that town, because it is a fact that the reputation a distributor has for giving service very often makes or loses sales for him, especially if he is handling a car of the better grade.

The time will come when a sign reading "Authorized Service-Station" will mean that the operators of the shop are using equipment that has been approved by the builder of the car whose name appears on the sign, and that the work will be done according to approved and standardized methods as far as possible. It is even possible that the price charged will be standard except for such variations as are necessitated by the difference in overhead expense and wage scales in the different localities. Then such a sign will mean that the factory is standing back of its service plants with a guarantee as to both quality and price. I believe that under those conditions the automobile owner would not turn his car over to an irresponsible mechanic who is operating a one-horse garage any sooner than one would take a typewriter or a dictaphone to a machine-shop to have it repaired. When that time arrives, the word "service" will have a definite meaning to the manufacturer and to the purchaser of the unit.

B. M. IKERT:—I have noticed in several instances that changes in cars that would facilitate certain operations could be made at a slight cost. In one case the flywheel is put on with cap-screws; the main-bearing cap cannot be dropped because it hits the cap-screws. It can be done by sliding the bolts out of the bearing but, to get those out one must reach up behind a plate with a little wire-hook and one cannot see to do this. That could be overcome, as one mechanic told me, by fitting flat-head bolts and providing some sort of key to prevent the bolt from turning on the other end. If that were flush with the flange, the whole bearing-plate would drop right down and all the trouble would be ended. To do that might require some retooling of the factory, but it would help very much. The same sort of thing is true of many other installations. These are only small items, as a rule, but they are just nasty enough to tie up the whole job.

Another instance is that of a fan-belt on a car. I can see no reason why the manufacturer could not have set the radiator about ¼ in. farther forward; as it is, the distance between the radiator and the fan-pulley is just a trifle less than the width of the belt, which is a pretty heavy belt. To take the radiator off is such a difficult job that, rather than do so, the mechanics take a bar and pry the radiator far enough away so that they can jam the fan-belt between the pulley and the radiator. A thing of that kind is discouraging to the service-man. One man said that the parts are all designed well and are pretty clean-cut but that he ran into difficulties when one assembly is made out of them. One particular engine that I looked at a year ago was an excellent one but, when

it was installed in a chassis, it would puzzle a service-man to get at the valves and other similar parts because the steering-gear and the carbureter interfered, wires prevented taking the plates off, and the nuts could not be reached with a wrench.

One large accessory company that makes speedometers has records of the length of time required to take a speedometer out of a car, work on it and put it back. In some cases it runs as high as 1 hr. to get at the job after the shaft has been taken out. In such a method as Mr. Whyte mentioned the assembly of the speedometer is right in front of the driver; by the removal of two screws a plate is released and the speedometer can be pulled out. A service-man could do that job in about 5 min. All of the other units are grouped about this one and all the connections are made at one point on the steering-column; so, the chassis wiring can be hooked to one side to take the body off. Car painters have told me that frequently the greatest charge they have to make in refinishing a car is for rewiring it. I recall one instance of inaccessibility in which the body had to be pried up to take a storage-battery out of a car, because the body overlapped the battery so far that the battery could not be removed except by doing all this really unnecessary work.

COMMERCIAL-BODY SUPPLY AND SERVICE

BY C. M. MANLY AND C. B. VEAL

SPECIFYING the four general plans that have been followed by chassis builders in securing body equipment as being the building of bodies in their own shops; on contract by the body maker to plans and specifications of the chassis builder; by a local body maker to the order of the dealer or the owner; and the assembling from stock of standard sectional units recommended by the dealer or selected by the owner, the authors discuss each of these plans in detail.

With regard to the plan of using standardized sectional bodies, the different sizes of chassis used for commercial purposes are separated into four specified groups and the production of a complete standard line including a number of styles of body for each chassis is commented upon and illustrated, inclusive of detailed considerations of the all-metal body. The advantages to the dealer and to the user of the factors that are advocated in body building are enumerated, and the standardization of commercial cars and trucks is considered briefly.—[Printed in the March, 1922, issue of THE JOURNAL.]

THE DISCUSSION

PRESIDENT B. B. BACHMAN:—There are two fields in the study of what the characteristics of bodies should be; one is the engineering and the other is the salesmanship field, but, it seems to me that, as with practically everything else, the engineering field comes first. In the commercial-car field there is no doubt that the influence of the horse-drawn vehicle with regard to body types has exerted practically a predominating influence; the study of bodies, as such, to harmonize with motor-truck chassis has been more or less confined to the so-called mechanical body for handling specific types of material, in the form of a dump body for handling solids or of a tank with a pump for the handling of liquids. The other bodies are inherently horse-drawn types and they have not advanced very far from their prototypes. This may be justifiable and no advance is possible but, because the unit that is hauling the load is so entirely different in its characteristics, it would be very strange if the old type of body that was most effective should be the most satisfactory for mechanical propulsion.

The outline of unit construction that Messrs. Manly and Veal have made is most interesting. Undoubtedly there are certain difficulties that will suggest themselves. Probably the principal one is the differences in type of various chassis. Many of those can be overcome largely by adherence to the work that has already been done by the Standards Committee and what may be done further, but there are some limitations, of course. I can see readily that the lighter unit, on chassis that have been standardized in other ways and are more or less similar in general type, probably offers a larger field due to both the similarity and the larger volume than those units in the strictly heavy class, and I can understand also why the question of volume, even if everything else is taken into consideration, probably drops down into relatively small proportions to get the advantages of a real production program.

P. H. WILLIS:—As to the advisability of standardizing on heavier types of body, the company I represent has had considerable experience and more or less remarkable success in such standardization on a few strictly standard types, and most particularly in standardizing several types of platform for chassis and trucks. The engineering on the bodies can be handled more easily because we can eliminate excessive widths and build the sills on the proper widths with the strength more evenly distributed. This works out very well. We have branches in different cities to which we ship knocked-down machine-parts. We get a lower classification rate in this way and can ship the body parts as cheaply as we can ship the raw lumber, thus saving excess freight.

J. E. SCHIPPER:—Some time ago I investigated this matter of standardizing certain features of the chassis to eliminate the tying up of a considerable amount of money in partially fabricated bodies. Such a thing as the distance between the side-rails of the chassis on vehicles of definite capacities varies to a considerable extent, although there is not very much reason for it; in fact, I believe that it could be standardized readily and that the Society has the matter under consideration. It seems to me that one of the reasons for high prices is the tremendous stock of material on hand in a raw condition and also in a partially fabricated state awaiting orders from body users for some definite chassis. For example, a dump body, which might be applicable to a 2 or to a 3½-ton chassis, can be made up just as far and no farther until the body-builder knows exactly what make of chassis it is to be installed upon. A little work in the direction of the standardization of parts of the chassis that have to do simply with the attachment of the body might result in great economy for the truck-body industry. When I looked into this subject a considerable time ago, there seemed to be a great amount of interest in it on the part of the body-builders.

C. M. MANLY:—Our reason for preparing this paper is that we feel that anything that can be done to cheapen transportation is certain to have a great effect on the increase in the demand for such transportation. Therefore, original or first cost and also the cost of maintenance, which involves a continued use of the truck and the avoidance of tieups as well as the saving in actual

cost of repairing, are very large items in this matter of commercial bodies. The portion of total cost of the complete vehicle that the body represents is a considerable item. Everything that can be done to decrease the cost arising in connection with it is certain to have an important effect on expanding the field of automotive transportation.

We are very much interested in getting the largest amount of available information, especially from the users, in connection with experience on bodies that have been made, and what their defects are. This applies to bodies that have been either custom-built or built in any other way. It is of interest to ascertain the viewpoint of transportation engineers in regard to what they feel is possible in the way of standardization of types; also to get all the data possible as to the things that limit standardization in connection with the chassis. The matter of having every width of chassis frame from 32 to 40 in. for the same sizes of truck is exactly in line, apparently, with many of the other variations that formerly existed in connection with what the position of the bolt-holes and engine legs and other engine-installation dimensions should be. Standardization must play an even more important part in all automotive work if we are to reap the benefit of the large foreign trade that we must have if we are to utilize the automotive producing facilities of this Country to their fullest extent. I believe there is nothing that will count more in obtaining that foreign trade than extension of our standardization work as affecting the question of service.

PRESIDENT BACHMAN:—I think that neither the body-builder nor the chassis designer can outline the limitation individually; it must be a combination of the two. Some things made certain characteristics of chassis design necessary; other things are not necessary. At times we try to reduce the chassis widths so as to get as short a turning-radius as possible and the steering-gear will be out beyond the crankcase; many things must be considered.

F. A. ANGLER:—In operating a fleet of 25 to 30 trucks I find that we can reduce our costs on bodies by standardization. After having tried to build bodies in our own shops, we find we cannot do this, even to our own specification, at anywhere near as small a cost as that of an assembled body.

E. W. TURLEY:—We have occasion during the year to buy a considerable number of bodies in different parts of the United States. If a body is built for a certain model of 2-ton truck, I doubt that this body will fit on any other 2-ton-truck chassis. If we could buy 40 bodies for 2-ton trucks, all of the same size, we probably could get them built more cheaply than they are being built at present. The bodies we buy cost from $350 to $400. Each time we buy a different make of truck, we must have a body made for that particular truck. What we have done is to use a tracing-cloth drawing. When the repair bills on bodies show that some certain feature is breaking down, we change the tracing so that the next blueprints that are sent out will be an improvement upon the old body. If the distance from the end of the frame to the driver's seat were measured on each make of 2-ton truck in use in the United States, I doubt whether any two would compare closely enough to prevent the necessity of having a body of different size built for each one of those chassis. If the chassis were standardized, even to this degree, for say 1½, 2 or 2½-ton truck sizes, we could buy all of the bodies we need for the entire year at one time and save considerable money. It would be desirable to ship these bodies knocked-down. We often have to buy bodies locally, on account of freight rates, and take the chance of getting a local body-builder to build them according to blueprints. He may not follow our blueprints, with the result that we do not get as good a body as we would like to have.

MR. WILLIS:—I think it would be asking too much of the automotive industry to require it to standardize on a certain length of chassis for a certain width of truck. For instance, a 2-ton truck hauling barrels has about a 40-ft. wheelbase. We could hardly standardize on certain sizes of body. A 14-ft. body might be required on a ½-ton truck to haul paper boxes. But we have never had so much trouble in mounting bodies on various widths and lengths of frame as we have had with cabs. The latter demand more standardization. There is a great difference even in the different models of the same make of truck in the dimension on which we must determine the cab body. The dashes on trucks vary in width from 28 to 72 in. No standard cab-body would accommodate itself to that variation in dashes. Some truck builders wish to save all the frame length they can for the body; they may put the driver right up on the dash and give him 27 in. to fold-up in. Another company may go to the other extreme, so that the driver must almost lie down in his seat to reach the clutch-pedal. We have those conditions to meet in fitting cab bodies.

Another condition is that some springs are low and some high. To put pneumatic tires on a truck that has a low frame, we must build-up the sills under the body and the body is not stable on the low frame. Sometimes we get a high frame and a low body is wanted on it; we cannot make the sills thin enough to accomplish that.

We have more trouble with the cab body than anything else. If there is to be any standardization, I think it ought to be on the front end rather than on the rear.

GEORGE S. CAWTHORNE:—The Society has sent out a questionnaire asking for data, with a view to standardizing truck cabs. The dimension from the dashboard to the center of the seat box is one of the main dimensions in the standardizing of cabs. I think it can be standardized because a driver requires just as much room in one truck as in another.

C. B. VEAL:—I think that the present recommended practice of the Society will go a long way toward clearing up the situation so far as mounting is concerned, for the larger sizes of truck. I do not know whether the body-builders generally are aware that there is any such recommended practice. The next move, as I see it, is on the part of the truck companies. The truck builder should be made to realize that standardization is to his advantage. There is no need of making trucks unless they can be sold; selling them is the trouble today. One cannot sell trucks or bodies, but only transportation and service.

What Mr. Willis said about the possibilities of building standardized heavy bodies is true, but the man who attempts it is hampered in many ways, one of which is that he cannot turn out just one thing continuously. Ford bodies can be made day after day and they will all fit Ford chassis because they are all alike, but that cannot be done for the large truck. Parts of them can be turned out and various combinations of parts can be distributed so that, by drilling enough holes, making enough changes and making them sufficiently special, a branch station can accumulate enough different things finally to bolt them together and get some different combinations of body. But the body-builder is handicapped; he cannot give the best service under such conditions.

More Car-Miles per Gallon of Fuel

By O. C. Berry[1]

Detroit Section Paper *Illustrated with* Charts

ECONOMY tests carried out in France indicate that it is possible to obtain a larger number of miles per gallon from cars made there than from cars made in this country. The author states that it would be well to make a careful study of the factors influencing car economy and to assure that our future car models take full advantage of all possible means of increasing their economy.

Figures are presented showing the extent to which economy can be increased by changing such factors as the carbureter adjustments, time of the spark, rear-axle ratio and speed of driving. A car that normally will go 21 miles per gal. under favorable test conditions at 20 m.p.h. was increased to 43 miles per gal. at 20 m.p.h. The study is not completed, but it has gone far enough to demonstrate its value. This progress report is presented to stimulate thought.

THE American automobile has been developed to a stage where it is a remarkably reliable vehicle. The hundreds of different makes of car do not vary in economy much more than their differences in weight would account for, and the offhand conclusion logically would be that there is probably not much more room for improvement in economy than in mechanical reliability. In this connection the recent economy tests in France are of interest. A Voisin limousine weighing 5300 lb. ran 28.3 miles per American gal. A Citroen car weighing 2500 lb. traveled 53 miles per gal., and a Petit-Peugeot car, weighing 1200 lb., 76.9 miles per gal. Contrasting these figures with the performance of the average American car makes it evident that the margin for improvement is indeed great. Probably no one feature of American cars has received less careful attention from automotive engineers than the capacity for economical running. No fuel-economy features are incorporated in the European cars mentioned that we do not know about and understand, and I do not concede for a moment that the foreign engineer is one whit more resourceful or well informed than the American. It is therefore incumbent upon us to look the situation squarely in the face and, recognizing the importance of fuel economy, to study carefully all of the factors influencing the number of car-miles per gallon of fuel, and to make certain that every possible improvement is included in the design of our future models.

Carburetion

One of the outstanding reasons for the poor mileage of the average American car is poor carburetion or, more accurately, poor carbureter adjustment. To make this clear, it will be necessary to show the effect of the richness of the fuel-mixture on the power and economy of an internal-combustion engine. In studying this point, use was made of a Willys-Knight engine mounted on an electric dynamometer. The results of these tests are shown by the curves in Fig. 1. In these curves the number of pounds of gasoline per pound of dry air in the fuel-mixture is plotted horizontally and brake horsepower and percentage of thermal efficiency are plotted vertically. In carrying out the tests the throttle was arranged so that it could be securely fastened, and all of the tests were run at a constant engine speed. The gasoline was weighed to 0.01 oz., the air metered to 0.10 cu. ft. and the brake-load, speed and temperatures were carefully measured. Under these conditions and with the carbureter adjusted to give a rich and powerful mixture, the first test was run. The power, efficiency and mixture ratio were then computed, and a point established on both the power and the efficiency curves. The gasoline adjustment was then made slightly leaner, the brake-load adjusted to produce the correct speed, and a second test was run. This procedure was repeated until the mixture became too lean to allow proper engine performance. More gasoline was then introduced each time until the mixture was entirely too rich. The mixture was thus made alternately richer and leaner until a sufficient number of points had been located on each curve to indicate clearly the effect of the richness of the fuel-to-air mixture on both the power and the efficiency of the engine.

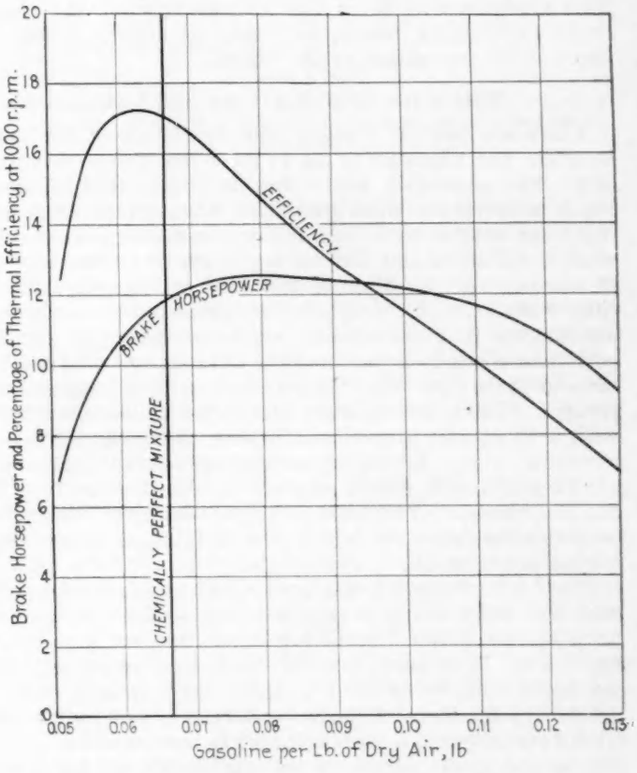

Fig. 1—Curves Showing the Results of Tests to Determine the Effect of the Richness of the Fuel-Mixture upon the Power and Economy of an Internal-Combustion Engine

It will be noted that there is a wide range of mixtures through which the richness has little effect on the power of the engine. The lean and the rich mixtures give

[1] M.S.A.E.—Chief engineer, Wheeler-Schebler Carburetor Co., Indianapolis.

equally good power, and both result in what seems to be perfect engine performance. This accounts for the fact that the comparatively crude carbureters of earlier days gave mainly satisfactory performance.

The range of mixtures giving the highest efficiency is very narrow, and corresponds to about the leanest mixture with which the engine will run without missing. As more gasoline is added, the efficiency drops off very rapidly; the richest mixture producing full power will result in only about one-half of the maximum efficiency. This explains why it is that of two cars of the same make performing nicely, one may go nearly twice as many miles per gallon as the other.

Why Over-Rich Mixtures Are Used

There are several reasons why nearly all of the carbureters are adjusted so as to give too rich a mixture when the engine is hot. One is that gasoline flows much more slowly when cold than when warm, an opening large enough to deliver the required charge to a cold engine will inevitably deliver too much when the engine is warmed-up. Another is that cold air is more dense than warm air; the weight of air delivered through the air-opening in a carbureter is greater when the air is cold than when it is warm, thus causing the mixture to become richer as the temperature of the engine increases. Thus, the mixture furnished by a carbureter with a fixed adjustment will become richer as the temperature rises. To make matters worse, not nearly all of the gasoline in a cold mixture is vaporized so that it can be burned. This makes it necessary to supply a considerable excess of fuel in a cold mixture to get the engine to run at all.

The American public has been taught to demand a car that will start easily in any kind of weather and continue to run without requiring any attention or adjusting. They have been supplied with a large variety of non-adjustable, or what has aptly been termed "fool-proof," carbureters. These carbureters will deliver a mixture rich enough to start well in cold weather and, due to the great range of the explodable mixtures of gasoline and air, will seemingly keep the engine running perfectly with full power, in summer or in winter. The only fault to be found is that, when the engine is hot, the mixture is much richer than is necessary and the number of miles per gallon is correspondingly low. A non-adjustable carbureter cannot be made so that it will make starting easy and also give high efficiency in driving.

A carbureter adjusted for maximum economy on a hot engine will deliver too lean a mixture to start with when the engine is cold. There are two ways in common use for meeting this situation. One is supplying a choke to shut-off the main supply of air to the carbureter, thus enriching the mixture. The other is providing a means of adjusting the carbureter from the dash or the steering-post of the car.

The action of the choke is very severe. It causes raw gasoline to be sucked into the engine in large quantity. Its action becomes increasingly severe as the engine speeds up; if the mixture is rich enough to start the engine it will increase in excess fuel as higher speeds are reached. This makes it necessary to readjust the choke every time the speed is changed.

The dash adjustment can be made very satisfactory in action if it is used correctly, and convenient as well. Its use is easily understood, because the idea is to get it set as lean as possible; it is very easy to tell when it is too lean, for the engine will lose power and backfire through the carbureter. A proper dash adjustment set right for one speed and load will be correct at all speeds and loads at the same temperature, and will need to be changed only as the temperature changes. The mixture should be just right for a hot engine with the dash adjustment set at its leanest position.

Discussion of Curves

The curves in Fig. 1 show that a richer mixture is required for maximum power than for maximum efficiency. It is therefore obvious that a carbureter adjusted for maximum miles per gallon will deliver too lean a mixture to give the full power of the engine.

This difficulty can be obviated in the following manner. When driving on a level road at any speed the law allows, the engine is never called upon to deliver nearly its full power. Under these conditions the most important consideration is economy. When a steep hill is to be climbed, acceleration is desired or a neighbor wants to race, full power is the important thing. The constant-speed driving is done with the throttle pretty well closed, and the power work with the throttle wide-open. It is possible to design a carbureter that will furnish the engine with the most economical mixture at all ordinary speeds on a hard level road, and with the most powerful mixture when the throttle is wide-open.

The fuel is almost never entirely vaporized in the intake-manifold of the engine. A considerable portion flows along the manifold walls as a liquid, lagging behind the air that passed through the carbureter with it. When the engine is idling this layer of liquid is very thin, but under full load it usually forms a fairly large stream. When the engine is put under load quickly, the air rushes ahead and leaves at least a portion of liquid on the manifold walls. If the mixture is lean enough to be efficient under steady running conditions, this temporary impoverishment will often be sufficient to stall the engine. It is therefore necessary to incorporate in the design of the carbureter some special means of temporarily enriching the mixture during acceleration. There are many types of construction in use, some of which are very satisfactory. It is therefore possible to obtain perfect acceleration, even when using a mixture lean enough for maximum efficiency. The more perfect the manifold design is, the easier this becomes and, with the very best manifolds, very little special provision is necessary for acceleration.

The Ideal Carbureter

In my estimation the highest type of carbureter yet developed for American gasoline will

(1) Furnish the engine with the most efficient mixture when the car is driven at a constant speed on a hard level road
(2) Provide the engine with the most powerful mixture when the throttle is wide-open
(3) Make perfect acceleration possible, even when adjusted for maximum economy
(4) Have a dash adjustment that will make starting and warming-up an easy matter, even in the coldest weather

There are carbureters on the market that meet all of these requirements. They make a greatly increased number of miles per gallon possible, and are more satisfactory to handle than the cruder fool-proof varieties.

The Timing of the Spark

The second factor influencing the economy of the automobile is the timing of the spark. If the spark passes too early it will lessen the power of the engine and tend

to produce what is called a "spark knock." If it passes too late it will also reduce the power of the engine. The proper timing of the spark in any given engine will vary with two things, the load the engine is carrying and the speed at which it is running. Nearly everyone knows that the faster an engine runs the earlier the spark must pass to give best results. The load condition has received comparatively little attention, and I will therefore enlarge upon it.

In making a study of this point an engine was mounted on an electric dynamometer in such a way that the exact time of the passing of the spark could be read, as well as the speed of the engine and the brake-load carried. The engine was run through a series of different spark-settings at each of a series of different throttle-openings. The results of these tests are shown in Fig. 2. In the curves the lead of the spark in degrees on the flywheel is plotted horizontally, and the brake-load carried is plotted vertically. All of the tests were made at 1000 r.p.m. Each curve was made at a constant throttle-opening, the brake-load being changed along with the spark-timing to keep the speed constant.

It will be noted that a lead of 20 deg. is required for maximum power at full throttle, and that a lead of 25 deg. will result in a knock. As the throttle is closed gradually, the lead required for highest power is increased until, with the lightest load carried, a lead of 40 deg. is required. At this throttle-opening the engine will carry only 60 per cent as much load with a 20-deg. spark-lead as with a 40-deg. lead. It is so disagreeable to have an engine knocking during acceleration and hill-climbing that the spark is almost never advanced beyond the point where knocking occurs at full load. Since the engines in our American cars run at such a low percentage of their power capacity, the spark is timed much later than it should be for greatest economy, which results in a considerable loss in miles per gallon.

The vacuum in the intake-manifold of an engine varies in almost inverse ratio with the brake-load carried. It therefore follows that the lead required by the spark at a light load, beyond that required at full load, will vary

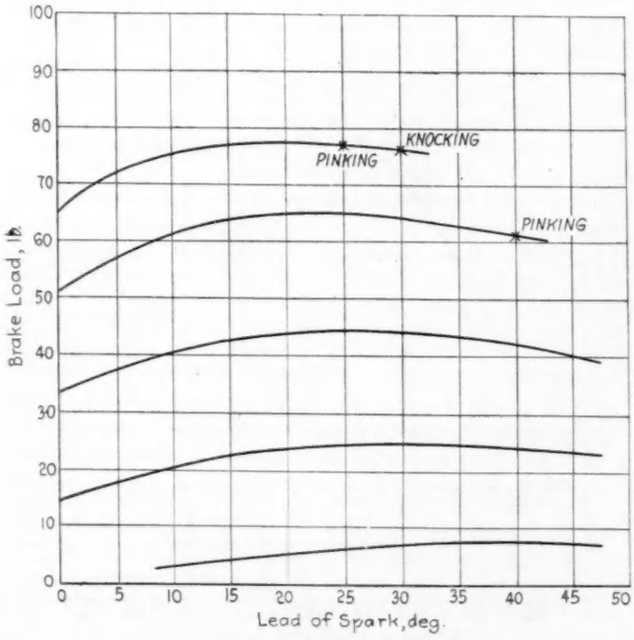

FIG. 2—RESULTS OF TESTS TO ESTABLISH THE RELATIONSHIP BETWEEN THE LEAD OF THE SPARK AND THE BRAKE-LOAD

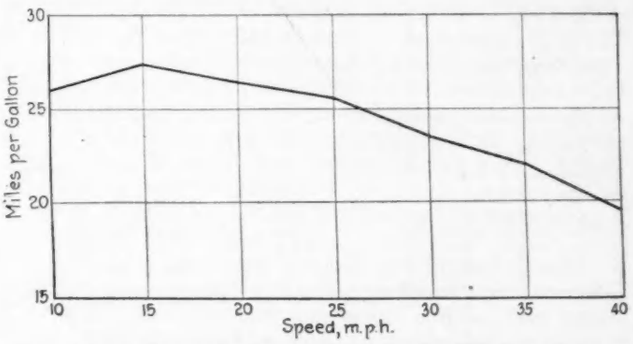

FIG. 3—CURVE SHOWING HOW CHANGES IN THE SPEED AT WHICH A CAR IS DRIVEN AFFECT THE MILEAGE OBTAINABLE FROM A GALLON OF GASOLINE

directly with the intake-manifold vacuum. This fact has been made use of in producing an automatic device for changing the time of the spark to correspond to the load carried. When properly installed, together with a standard controller compensating for speed, this device provides a completely automatic and very accurate means of timing the spark. This device is not on the market at present, but I have conducted a series of tests showing its merit and feel confident that it will be perfected and presented to the public in the near future. When properly installed, it should add considerably to the economy obtained by the average driver.

The speed at which a car is driven will cause a considerable variation in the economy obtained. This is shown in Fig. 3. The tests here reported were made on a hard level road, running in both directions over a carefully measured course. The car was tested with the top and windshield up and at a weight of 3100 lb., including the driver and the observer. Cars of this make probably will average about 21 miles per gal. under test when in the condition in which the average driver keeps his car. By freeing the brakes, having the spark accurately timed and the carbureter carefully adjusted, the record indicated by Fig. 3 was obtained.

THE LOAD ON THE ENGINE

Another opportunity to improve the economy of our automobiles has to do with the large reserve power in the engines. A good American car can climb a steep hill in high gear, and accelerate very rapidly. This delightful "activity" necessarily means that under ordinary driving conditions on a hard level road the engine is called upon to exert a very small percentage of its full torque capacity. To get accurate information on this point, a car was chosen of a make known to be carefully designed, well built and having a good average accelerating ability of about 3.2 ft. per sec. per sec. Tests were made showing the torque capacity of the engine and the power required to propel the car at varying speeds. The results of these tests can be taken as representing the average performance of good American cars.

The method of conducting the tests was to insert between the carbureter and the intake-manifold a plate having a hole drilled through it that would serve as a throttle-opening. A determination was then made of the maximum speed the car could attain on a long stretch of hard level road with this orifice in place. This test was repeated with a number of orifices of different sizes. With the engine removed from the car and connected to an electric dynamometer, tests were run to determine its torque capacity at varying speeds with each of the orifices in place. Knowing the size of the rear

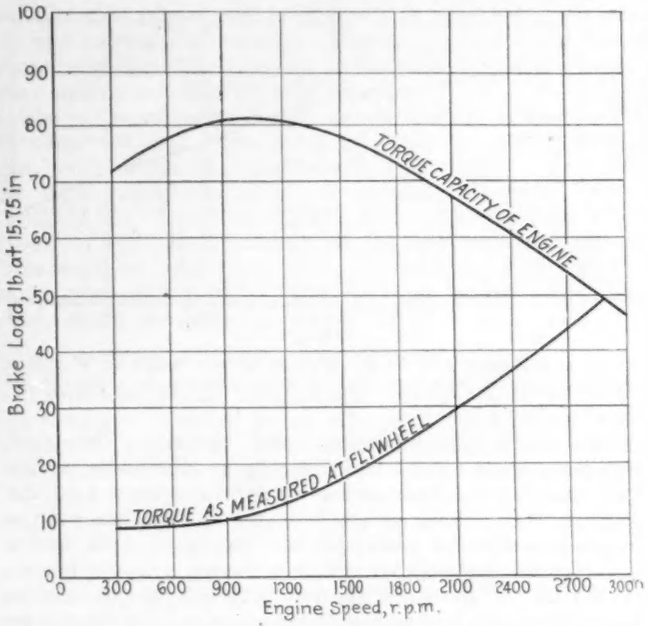

FIG. 4—RESULTS OF TESTS MADE TO OBTAIN THE TORQUE REQUIRED TO DRIVE THE CAR AT VARIOUS ENGINE SPEEDS AND THE TORQUE MEASURED AT THE FLYWHEEL OF THE ENGINE

wheels and the gear-ratio, the engine speed corresponding to any car speed is accurately known. The torque required to drive the car at any one of these maximum speeds for a given orifice is the torque capacity of the engine at that speed with that orifice, as shown by the dynamometer tests. The results of these tests are shown in Fig. 4. In these curves the engine speed is plotted horizontally and the brake-load at a radius of 15.75 in. is plotted vertically. The upper curve shows the torque capacity of the engine and the lower one shows the torque, measured at the flywheel of the engine, that is required to propel the car at corresponding speeds. The distance between the upper and lower curves is therefore proportional to the reserve power of the engine, and represents its ability to accelerate rapidly or climb a steep hill.

In this particular car an engine speed of 1000 r.p.m. corresponds to 20 m.p.h. It will be noted that at this speed only about 14.7 per cent of the torque capacity of the engine is used when driving on a good road. Anyone familiar with the performance characteristics of an engine knows that this fact alone will account for a large reduction in the thermal efficiency obtainable from the engine under ordinary driving conditions. This is such an important consideration that a special series of tests was carried out to show the exact situation.

EFFICIENCY AT DIFFERENT LOADS

It is well known that the brake thermal efficiency of an engine varies from zero at no load to a maximum that occurs at a little less than full load. Engines differ according to their design in ability to perform under different conditions, some doing comparatively better at light loads and others at full load. Tests were therefore carried out on the engine previously used to determine the effect on its thermal efficiency of changing the load.

The engine was installed on the dynamometer and run at 1000 r.p.m., at a series of different throttle-openings. At each throttle-opening a series of tests was run at different carbureter settings, similar to the tests plotted in Fig. 1, and showing the mixture corresponding to highest-efficiency at that throttle-opening, together with the corresponding power and efficiency. The brake-load was expressed in terms of brake mean effective pressure, and a curve drawn through the points showing the highest efficiency at each load. This curve, shown in Fig. 5, indicates the maximum efficiency obtainable with this engine at each brake-load, the engine running at 1000 r.p.m. The efficiencies will vary as the speed is changed, so that this curve should be interpreted as applying only to the one speed.

The carbureter was adjusted leanly enough to give maximum economy at all loads until the throttle was wide-open. After this point was reached, the increases in power had to be obtained by enriching the mixture, until the full power was obtained. These richer mixtures result in reduced economy, thus causing the curve in Fig. 5 to show a decided drop as full power is approached. This curve therefore offers one more illustration of the importance of using lean mixtures when high economy is desired.

Fig. 5 shows how important it is to run the engine under a comparatively large percentage of its full-load capacity. Since the miles per gallon of any car under given running conditions will vary directly with the thermal efficiency of the engine, a change in the load factor on the engine can result in greatly increased economy. This fact was checked in part by installing a different rear-axle ratio and noting the change in the car economy. The standard ratio was 4⅞ to 1, and resulted in a load factor of 14.7 per cent at a speed of 20 m.p.h. Under these conditions the car could go 28 miles per gal. when loaded so as to weigh 3100 lb. A gear ratio of 2½ to 1 would result in nearly twice the former load factor, and Fig. 5 shows that this should result in an increase in fuel economy of about 50 per cent, or to 42 miles per gal. Under test the car actually ran 43 miles per gal. These tests were all made with a

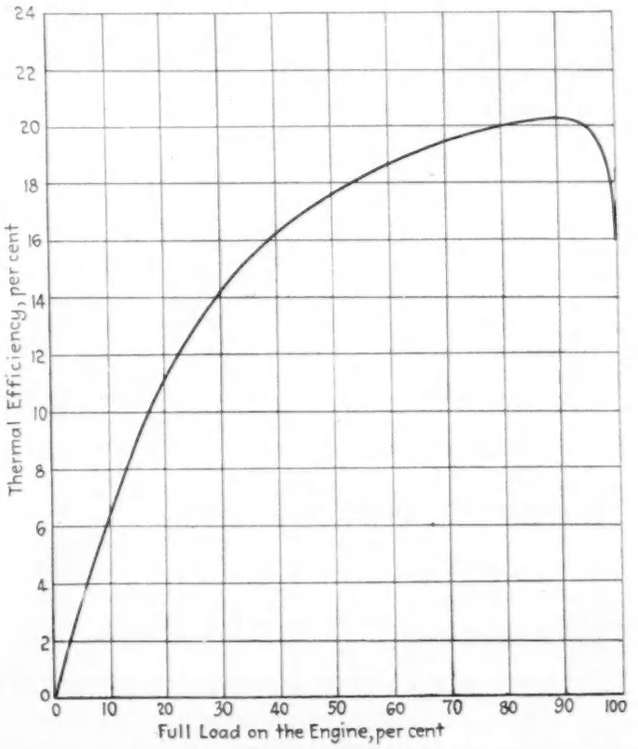

FIG. 5—VARIATION IN THE THERMAL EFFICIENCY OF THE ENGINE AT DIFFERENT LOADS

carbureter equipped with a dash adjustment to make starting easy in cold weather.

Efficiency and great ability to accelerate cannot be obtained at the same gear-ratio. The former requires that the engine run at a high percentage of its torque capacity and the latter the other extreme. We cannot afford to compromise the delightful activity of our cars. On the other hand, I feel confident that the first company to produce a car having the activity to which we are accustomed and capable also of going more miles per gallon than any other car of its weight in the Country, will become both rich and famous. We can accomplish this if we have four speeds forward. Third speed could be called the "power" or "speed" gear and the fourth the "economy" gear. Such an arrangement would be beneficial by

(1) Greatly increasing the miles per gallon
(2) Reducing the engine vibration at the common touring speeds
(3) Increasing the speed at which one could tour with comfort and satisfaction on good roads
(4) Enabling one to tour at high speed with the mental satisfaction that would result from knowing that one is not punishing the engine, while any other car at the same speed would be going entirely too fast for its own good
(5) Greatly reduce the wear on the engine, thus prolonging its life and reducing maintenance costs

The disadvantages are that (*a*) the four-speed transmission would be expensive when sufficiently well-made to run quietly on two gears and (*b*) the gears would need to be shifted more often.

The possible advantages are therefore fundamental and far-reaching and the disadvantages of a practical nature and, although difficult to overcome, not too difficult for automotive engineers when they really become interested in mastering them.

Education of the Buying Public

The automotive engineer gives more attention to designing a car that will sell well than to making it meet his ideas of perfection. Our fuel has been cheap and plentiful and economy has not been demanded by the average buyer. He has rather been taught to demand a car that will accelerate well and climb any hill on high gear. He seldom stops to think how much the activity of his car costs him in gasoline, oil and repairs. He has never been educated to see how much can be gained by accepting different standards of performance. The automotive industry should make it a point to get this information before the public and thus create a demand for a more economical car.

The driver is not aware of how much fuel his car is using as he rides along and is accordingly not apt to handle it economically. For this reason it will be well for us to give the flowmeter serious attention. Such an instrument has great possibilities as a means of educating the public to demand greater economy in their care and would logically result in cars being kept in better mechanical condition. If a flowmeter can be developed that will never cause trouble, it should be installed as standard equipment on all new cars. It has already been developed to a point where it can unquestionably be made of value to the service-man.

Economy Contests in America Desirable

It might be well to run a series of economy tests in this Country similar to those that have been carried out in France. Unfortunately, a number of American engineers have questioned the practical value of these tests. They state that the carbureters are adjusted so leanly in these tests that the cars are incapable of good general performance and would be unfit for general use without changing the carbureter adjustment. As a matter of fact, it is possible to build a carbureter that will perform well even when adjusted for maximum economy, and these tests would prove this. In planning such contests a careful set of standards of performance should be established. These standards should be high and every car required to meet them before taking part. Under these conditions the results would be of real practical value and lead to wonderful development in the way of a public demand for an economical car.

By applying the ideas brought out in this paper to a standard representative car, its mileage was increased from 21 to 43 miles per gal., under similar test conditions. Our knowledge of how to increase car economy is not yet complete. There are factors influencing miles per gallon that are not mentioned here. This paper is merely a progress report presented at an early stage. I feel however that it has gone far enough to demonstrate the value of the study and warrant a conviction that American engineers can be depended upon to produce cars showing economies that now seem almost impossible.

By lessening wastes in running and storing petroleum, by perfecting the processes of making gasoline and especially by developing ways of producing substitute fuels economically and in large quantities, the chemists of the Country can help make it possible for future generations to ride in automobiles. In the meantime, automotive engineers should be steadily increasing the economy of our cars and thus add to the value of each gallon of available fuel.

THE DISCUSSION

W. S. James:—Regarding the comparison Mr. Berry made between American and foreign-built cars, it should be borne in mind that the European tests he quoted were run under very special conditions. When driving around the curves, if a driver slowed-down very much his engine usually stopped. All the cars were adjusted for very economical running to obtain the maximum number of miles per gallon of fuel. The Petit Peugeot car weighed about 1000 lb. and gave a performance of 70 miles, or 35 ton-miles, per gal. Let us compare this with the Buick performance. The Buick weighed at least 3000 lb. and gave 20 miles per gal., or about 30 ton-miles per gal. There is little doubt that, under special conditions similar to those existing in the tests discussed, the Buick performance could be increased to 25 miles per gal., which would mean about 37½ ton-miles per gal. or a figure at least as good as that of the Petit Peugeot.

I had an opportunity in Europe to obtain manufacturers' statistics on the fuel mileage of European cars and compared them on the basis of ton-miles per gallon with similar statistics from American companies exhibiting cars at the New York Automobile Show. The figures can possibly be taken as equally optimistic in both cases. The results of the comparison showed that the number of ton-miles per gallon obtained from cars in France was no greater than the average number of ton-miles per gallon obtained in the United States. In England the number of ton-miles per gallon is possibly 10 per cent greater than in the United States. In both instances, however, the average number of miles per gallon is greater by possibly 20 per cent in England and from 10 to 15 per cent in France. This simply means that we are building heavier cars, with engines of at least the same efficiency.

Using the volume of air drawn into the engine per ton-mile as another basis of comparison, American engines draw in about 30 to 35 per cent more air per ton-mile. This means that our engines run at more nearly closed throttle, and, as Mr. Berry pointed out, our pumping losses are very much greater. In spite of the fact that our engines pump 30 per cent more air, American cars are still only 10 per cent low in ton-miles per gallon. This does not mean that we are any farther behind European performance in actual engine efficiency, but that we are using heavier cars. In fact, at the New York Automobile Show, I could find only about four cars made in the United States that weighed less than 2000 lb., loaded. In England there are about 65 makes of car that weigh over 2000 lb. and 67 that weigh under 2000 lb.

If the amount of gasoline burned in internal-combustion engines is 4,000,000,000 gal. per year, and it were to flow over Niagara Falls at the mean rate of flow of the Niagara River or 222,000 cu. ft. per sec., it would take a little more than 40 min. to flow over the falls. The total volume of crude oil from which this gasoline was produced would require over 2½ hr. to flow over the falls. This helps us to understand what a gain it would be to save only 10 per cent of that volume of liquid. Even a 1-per cent saving in gasoline on the average amount used in this Country would mean a large volume of liquid.

I thought I knew how to drive a car economically, but since I have had a gallons-per-hour flowmeter on my car I have changed my mind. I think Mr. Berry's point about the use of flowmeters was stated very well. The greater part of the waste of gasoline is not through the ignorance or the lack of application of the knowledge of the engineers, but through a lack of knowledge and information on the part of drivers all over the Country. If a driver had some sort of tell-tale that would indicate whether he was using more gasoline at one time than at another it would help to save gasoline. The instrument could be graduated to indicate dollars and cents per hour, or miles per gallon or whatever seemed desirable.

O. C. BERRY:—I do not wish to convey any unfavorable impression regarding American engineers or car performance in this Country. Some tests, such as Mr. Nelson's at Indianapolis, show performances considerably better than those of the French. But the performance of our cars in the hands of the average driver can be improved. The problem we are facing is to persuade the average driver to increase the number of miles he obtains from a gallon of gasoline.

P. F. HOWELL: — The flowmeter would no doubt be better understood if it were called a gasoline speedometer. It is an instrument that will indicate the amount of gasoline that is being consumed per hour when used in connection with an automobile, and gives the miles per gallon delivered by the car when read jointly with the speedometer. The instrument was developed about a year ago and was found to be of value when used in the final adjustment of new cars before delivering them. The volume of the distributor's business comes from the small contracts for from 5 to 20 cars each. This business is often rather expensive in regard to service and replacements of parts; the only possible way the necessary evil of servicing can be overcome is to furnish the dealer with cars that are accurately adjusted, eliminating the necessity of service after sale and delivery are made.

With such an instrument not only can a standard of carbureter adjustment be set but it can be maintained in spite of the poor help that is often the only help available. Nearly everyone in the automobile business thinks that he can adjust a carbureter accurately. This is not a fact, from a standpoint of efficiency and economy. But even inexperienced help can adjust a carbureter accurately by using a flowmeter, as has been proved. It has proved that some old-time theories are wrong. For instance, the general opinion was that 20 to 25 m.p.h. was the best speed to drive any car economically, but this instrument proves that the speed may vary from 12 to 30 m.p.h., depending upon the make of the car and its condition.

The procedure to follow, when adjusting and servicing motor cars, is to first jack the rear wheels off the ground. Start the engine, shift into high gear, speed up to about 20 m.p.h. and then move or change the carbureter adjustment until the maximum speed is indicated on the speedometer for the least amount of gasoline that is passing through the flowmeter. Then enrich the mixture by carbureter adjustment until the speedometer shows a loss in speed. Then watching the flowmeter reading only, set the flow at one-half way between "too rich" and "too lean" by altering the adjustment. This will result in the maximum amount of economy and power, no guess-work having been employed to set the carbureter accurately. After the carbureter has been set and while the car is still up on jacks and in high gear, speed up the engine until the flowmeter indicates 1 gal. per hr. Then note the speedometer reading. Change the spark-timing until the greatest speed combined with a smooth-running engine is attained. This should be noted as being a certain number of miles per hour to a certain number of gallons per hour. If any other adjustments are necessary, they should be cared for at this time. The result will be noted in the gain or loss of speed.

To complete the final adjustment of the entire car, the work should be continued by checking up the alignment, removing the friction from the driving members and releasing the brakes so that they do not drag. The proper quantity and kind of grease should be provided for the universal-joints, the differential and the bearings and, upon completing and making the necessary adjustments, the car should again be shifted into high gear, the engine speeded up until the flowmeter registers 1 gal. per hr. and the speedometer reading noted to see if any improvement in efficiency has been achieved from the work that has been done. If all this work has been thoroughly completed, the engine and the driving members will have been adjusted to their highest degree of efficiency, and the result in miles per gallon can be considered the standard to which other cars of the same make could, and should, be adjusted when upon jacks. The car should then be removed from the jacks and driven on the road. The miles per gallon should be noted and the oil, bearings, tires and other sources of friction cared for, to eliminate as much friction as possible and the attempt should be made to obtain more speed for the same amount of gasoline. The result in the end will be the maximum number of miles per gallon to which any motor car of this make can be adjusted, and this will be the standard in miles per gallon at which all cars of this make should operate on the road. The difference between the results on the road and on jacks might be termed "road resistance." This loss in miles per gallon might be termed the "standard loss" to be expected in this particular make of automobile. We have found in this way that it costs no more to condition new automobiles up to a standard, and costs much less for service,

because of being able to locate the trouble in less time. Often one adjustment is enough to bring a car back to its standard number of miles per gallon.

MR. BERRY:—No matter what we think about the value of the flowmeter for the production car, it is unquestionably a fine instrument for the service manager. I have driven with a flowmeter for about a month. I find that it tells why we do not get better mileage in winter. It takes as much gasoline to start the car on cold mornings as to maintain it at boulevard speed after it is warmed up. I do not know whether it will be possible to increase very materially the number of miles per gallon in winter on cars driven in the city, because one cannot cut down the gasoline to a close adjustment in winter; however, most cars are used in summer and on long drives. For those conditions we ought to be able to get almost the theoretical maximum output. It is possible with the American carbureter to cut down so that the maximum mileage is obtained in touring with a warm engine, still having plenty of power when needed.

GEORGE BREEZE:—Were the performances in France rated in United States or British Imperial gallons?

MR. BERRY:—I was quoting figures that had been reduced to United States gallons. They used benzol, which gives something like a 14-per cent better mileage per gallon than gasoline.

MR. BREEZE:—We equipped a Ford car with a dash adjustment such as you mentioned. It takes as much gasoline to warm-up the engine and get the car out of the garage as it does to run 1 mile afterward. It requires 1¼ turns of opening of the fuel-adjusting valve for the first ½ mile and 1 turn for the next 1½ miles. Up to that point the average is about 16 miles per gal. Thereafter it is 25 miles per gal., with about a ⅞ turn. That is with standard equipment. Running with special equipment and a ⅞ to ¾ turn will give 31 to 32 miles per gal, and a ¾ to ⅝ turn gives 37 miles per gal. I have found that one can cut the warming-up time in half by heating the mixture. Heating the mixture has more to do with warming-up the engine quickly, than anything else on Ford cars.

MR. BERRY:—I know of one foreman at the Ford factory who drove from Detroit to Indianapolis and return with his family and averaged 33 miles per gal. during the trip.

A MEMBER:—Mr. Berry said that the pumping loss is one of the greatest losses at low speed. Why cannot the carbureter be developed to obviate that pumping loss by reducing the engine speed and leaning the mixture, rather than by increasing the manifold suction. We have made many tests in running engines on gas instead of gasoline. To get the best economy, instead of running up or throttling the engine down, we kept leaning the mixture. In running the engines idle on gas instead of gasoline, we found that we used only about one-third of the fuel that we used when running the engines on any carbureter I have ever tested.

MR. BERRY:—The explodable range of a mixture of gas and air seems to be considerably wider than with gasoline vapor and air. The ideal carbureter I have endeavored to describe would be arranged to give the richness of mixture corresponding to the highest efficiency during the touring range that is as far as one can go in that direction. If the amount of gasoline is decreased below that point, we not only do not increase the efficiency but we decrease it. It is impossible then to continue to lean the mixture and control the engine in that way more than the carbureters are now doing.

MR. BREEZE:—Have you ever tried stratification of mixtures?

MR. BERRY:—No.

MR. BREEZE:—I have seen some experiments in that regard in certain classes of engines.

MR. BERRY:—I know that some experiments have been made on a design that is intended to handle the mixture in that way. I believe one particular engine has two combustion-chambers. The upper one is used for idling and low-speed running, and the main combustion-chamber is for higher power. The small combustion-chamber has always been fired first, the resulting high temperature and pressure making it possible to burn very poor mixtures in the main cylinder. The compression can be kept more nearly constant in an engine of this type. This engine is only in the experimental stages and I cannot give very much information concerning it.

AERONAUTIC SAFETY FUEL-TANK AWARDS

A SUBJECT that received much attention during the war, fireproof fuel-tanks for aircraft, was the basis of a recent competition in England, the results of which are reviewed in *Flight* for May 4, 1922, p. 261, and in *Aeronautical Engineering* for May 10, 1922, p. 336. The winning safety tank is described and illustrated in *Aeronautical Engineering* for May 17, 1922, p. 354.

Prizes were awarded to three successful contestants after a preliminary series of tests followed by final tests on four tanks of each of three makes, the latter tests including a firing test of five rounds from a machine-gun in which armor-piercing and incendiary ammunition was used, and a crash test in which the tanks mounted in a fuselage structure were crashed to the ground at a speed of about 50 m.p.h., this speed being considered far above that at which a pilot would have any chance of survival.

Three types of tank seem to have met these tests successfully. Two of them consist of specially designed sheet-metal, enclosed in rubber casings. The third is made of two rubber-composition containers, one within the other, separated by a space filled with a non-inflammable gas under a slight excess pressure.

The basis of award for the competition was as follows:

(2) Remaining attributes, 100 points maximum

(1) Crash-proof qualities, 100 points maximum

The second group was subdivided as follows:

Durability under service conditions in the absence of accidents	25
Indifference to extremes of temperature	25
Adaptability of design to large capacities	10
Simplicity of construction	10
Adaptability of design to various shapes	10
Accessibility of fittings	10
Cost of production	10

A practicable crash and fireproof fuel-tank for commercial aircraft should eliminate one element of risk that the general public considers very important in securing safety in aviation.

Principles of Motorbus Design and Operation

By G. A. GREEN[1] SEMI-ANNUAL MEETING PAPER

AFTER the presentation of this paper at the Summer meeting of the Society, it was discussed by some of the members present, and replies to various points raised were made at that time by the author. The stenographic report of this discussion has been submitted to those participating, for correction or amplification, and such changes, where received, have been incorporated in the report of the discussion printed below. For the convenience of the members, a brief abstract of the paper, which was printed in the July issue of THE JOURNAL, precedes the discussion.

ABSTRACT

IN the paper an attempt is made to answer the broader phases of the questions: What constitutes a bus? and In what respects does a bus differ from other classes of automotive equipment? by establishing the principles on which the design and operation of motorbuses should be based. The treatment of the subject is in the main impersonal, although specific references to the practice of the Fifth Avenue Coach Co. and illustrations of its equipment are made to emphasize the points brought out. The questions of the unwisdom of overloading, rates of fare and the service requirements are discussed briefly as a preface to the paper proper.

The factors controlling bus design are stated to be (*a*) safety, (*b*) comfort and convenience of the public and (*c*) minimum operating cost. The various subdivisions of each are commented on in some detail, and numerous illustrations and tabular data supplement the text. The conclusions reached are that trucks or automobiles, either modified or unmodified, are absolutely incapable of rendering satisfactory and economical service as buses; such failures of buses as have occurred were due to the combination of extemporized equipment, indiscriminate operation, overloading and lack of experience; and, if the Society would concentrate its standardization work on the motorbus, much good could be accomplished.

THE DISCUSSION

GEORGE W. CRAVENS:—Some years ago I had charge of locomotive design for the General Electric Co. Among the locomotives we designed were the first ones for the New York Central Railroad, which were made with the motors as the frames of the trucks. The center of gravity was very low; in fact, most of the weight was in the trucks and much of it was unsprung. The result was that the first time the New York Central locomotive tried to make high speed on some of the curves it tipped over, due to the fact that the rails tipped over because the center of gravity was so low and the weight mostly unsprung. I state that first because I want to ask Mr. Green if any of his experiments showed that the center of gravity might be too low for safety and for comfort, but especially from the standpoint of safety due to putting excessive side-strains on the wheels when striking obstructions in going around curves. I notice that he favors the steel wheel. I want to raise the question as to the effect of low center of gravity throwing excessive strains on the wheels, causing side-strains on the bearings and springs, and what effect that has upon the riding qualities as well as on the maintenance of the running-gear.

For interurban bus-transportation, has the double-deck bus ever been used successfully? Is it better on general principles outside of cities, where turning radius is not important, to use a short wheelbase with a double-deck or a longer wheelbase with a single-deck bus? About what does experience show as a fair average seating-capacity that should be satisfactory for the purpose?

HARRY A. TARANTOUS:—In Table 5 Mr. Green mentions a material charge of $759.81 for chassis repairs. Is there any cost for sleeve replacement during the year included in that? Is any special grade of gasoline used, or is a standard gasoline sold in New York City employed?

B. S. PFEIFFER:—Is there any difference in the gasoline consumption per ton-mile of the J-type and the L-type buses?

MERRILL C. HORINE:—There has been some talk of the danger of excessive overhang back of the real axle, because of the necessity of turning in congested thoroughfares. Is that really a factor and is there a possibility of side-swiping a neighboring vehicle on the turn?

It is a popular notion that the outside stairway is a danger, because of the possibilities of the passenger falling off. I myself have had to hold on pretty tightly in making stops on Fifth Avenue buses, but I have never fallen off. Did anyone ever fall off?

A very low frame and floor with ordinary-size wheels requires an exceedingly large wheelhouse which, in the case of some buses, entirely eliminates leg-room from at least two seats in the bus. Is there any cure for that, if it is found to be a real disadvantage in practical operation?

In connection with the flat floor Mr. Green advocates in the driver's compartment, that means that the driver has no toe-board. Does not that require the driver to ride the clutch continuously; if so, is there any objection to that if the clutch throw-out bearing is properly designed?

With further reference to the clutch, does Mr. Green favor the use of a clutch brake? I had not noticed much clutch-brake effect in shifting gears on Fifth Avenue buses, and I wondered if there is any reason for that.

I notice that the frames are straight in Mr. Green's designs. There must be a reason why he has not gone to the rather radical drop and gooseneck frames that we are beginning to see on some of the special bus designs.

T. V. BUCKWALTER:—On the question of height of center of gravity, Mr. Cravens has explained why they found it desirable to build a high-center-of-gravity New York Central locomotive, and asked whether that applies to our automotive practice. The first electric locomotives on the New York Central were built with a very

[1] M.S.A.E.—Vice-president and general manager, Fifth Avenue Coach Co., New York City.

low center of gravity and the motors were built on the axle. A rather small wheel for a locomotive, about 44 in. in diameter, was used, and it was found that the riding characteristics were very bad. The locomotive had an exceptionally severe surge on the rail; when the wheels struck a curve, they would hit the rail with a series of jerks. The rails would not stand up under this surging. I think it has been corrected by the redesign of the locomotive to use trailer trucks which ease the locomotive in going around curves.

Before the Pennsylvania Railroad Co. put its locomotives into service in 1910 at the time of the New York electrification, it built a series of Brinell testing machines, four of which were put on each tie, and these testing machines were spaced along about 1 mile of track. They tried out all the various kinds of electric locomotive they could obtain, in comparison with steam locomotives. After a high-speed run they would take the Brinell reading in horizontal and vertical directions on each one of these ties for possibly 1 mile of track, an expensive and laborious operation but well worth while in developing where the center of gravity should be. It developed from this test that the low-center-of-gravity locomotive had the most destructive effect on the roadbed and, as the other types of locomotive were tried out and the center of gravity brought up higher, as I recall it to between 70 and 80 in., the destructive effect on the roadbed and likewise on the locomotive was lessened, until they reached the old type of high-speed passenger-locomotive with 80-in. drive-wheels and the boiler set on top of the frame. One of the earliest of the high-up locomotives with a clear space under the boiler over the wheels was the easiest riding locomotive of them all; and it was the only one that attained a speed of 107 m.p.h.

To apply this to the automotive situation, I am inclined to believe the reason the low center of gravity is so destructive in railroad work is that the surging must be resisted by one set of flanges, the flanges on the outside of a curve; the inside set of flanges has no function in keeping the equipment on the track. The reverse is true in automotive practice. We have four flanges, flanges on both sides. The adhesion of the tires to the ground constitutes the flange action and, by keeping the center of gravity fairly low, we get the effect of double-flange action. In other words, the outside wheels possibly have increased adhesion due to the increased weight that is due to centrifugal force; their effect in keeping the vehicle on its road is reinforced by the weight remaining on the inside wheels. Therefore, I think it is desirable that the center of gravity be kept fairly low.

In regard to the future of the bus as compared with the electric railway, the railway men saw the electrical manufacturing companies practically develop an electric locomotive. One of the reasons for that is that the railway men are so set in their ways that they cannot get into the habit of thinking originally on a new line of work. Mr. Green has given us a fine example of original thought on a new problem. He has thrown into the discard the practices that he has seen on other lines of automotive apparatus and has attacked this problem with a clean slate, working out each of the various details as a problem to be attacked from the ground up. That his solution has been wonderfully successful, as it has, indicates that this is the proper procedure by which to handle a problem of that nature.

The railway men have not been inclined to do that. When the first rail-car bus came up for discussion, some of the earlier specifications were to the effect that it must have Master Car Builders' trucks, a buffing resistance through the center sills of 550,000 lb. and the like. All of that applied 10 to 15 years ago to the gasoline rail-car and, at that time, they would not permit us to disregard those features. The cars built at that time could not be anything but failures; a problem of that kind must be attacked as a new problem and we must forget all our ancient theory.

I feel that there is a great future for the motorbus because the bus can receive and discharge its passengers at the curb and leave the center of the street free for other traffic. I believe that this one feature alone will increase the capacity of our streets in larger cities at least 100 per cent; that is, double the traffic over a street that has electric railway equipment, which in a good many of our crowded communities, where the streets are not wide, requires the stopping and holding-up of all automotive traffic because of the presence of the track-confined vehicles.

The second great advantage of the bus consists of the facility with which additional buses can run by one that is stopping to receive or discharge passengers; whereas, in comparison, the track-confined vehicle holds-up all following traffic when stopping for any cause. In like manner, when any trouble does develop in a bus, it can be run up to the curb or into a side street without creating a general hold-up of traffic; whereas it is a common sight to see electric rail-equipment bunched, often due to some minor defect or adjustment that, until corrected, holds-up traffic on that particular track. To sum up, the track-confined vehicle has a general tendency to run in bunches; whereas the tendency of the self-contained bus-system is to distribute traffic over the entire route.

We have endeavored to approach the builders of street-railway equipment with the thought of modernizing some of their equipment. Their general line of defense is that, we aim to give our customers what they want. The electric-railway people, on the other hand, say, We take what the street-railway-equipment company has to offer, and that, because it does not offer certain things, we do not consider them. That vicious circle is one of the things that prevents the established companies from developing and it is one of the reasons why the gasoline motorbus will succeed ultimately and displace a considerable amount of our electric-railway equipment.

HERBERT CHASE:—To what condition does Mr. Green attribute the unusually low friction that he says is characteristic of the Knight engine? I am aware that his company is using or is planning to use an oil of lower viscosity than is used customarily for that type of engine, but I fail to see why the friction of the Knight engine should be lower than that of an engine of the poppet-valve type.

I am sure that Mr. Green will agree that the bus as it is developed today, even by the Fifth Avenue Coach Co., is not an ideal vehicle in all respects and that there are many possibilities of improvement. It is my belief that these possibilities should be considered; that they should not be overlooked, as they are apt to be, through an effort to apply our present-day type of engine, gearset and the like, to the problem rather than design a vehicle primarily from the standpoint of the service to which it must be applied. The steam-operated bus, for example, has certain inherent advantages, such as high starting-torque, smooth and rapid accelerating ability and the elimination of a gearset. These advantages are realized in the steam buses which have been used in London to some extent for many years. What are Mr. Green's views about the possibilities in this direction?

E. W. WEAVER:—In speaking of the necessity for economy, Mr. Green brought out the fact that a low speed of revolution of the engine per minute and slight opening of the throttle tends to give economy. With the throttle barely cracked the engine has a very low volumetric-efficiency. If it were possible with a different gear-ratio to cut the number of revolutions per minute in two and increase the efficiency, I think the gasoline consumption could be cut down. I am working on a proposition tending in that direction.

A. A. BULL:—In Table 5 chassis repair is all grouped under one heading. Would it be possible for Mr. Green to separate this item so as to indicate in a general way which part of the chassis or component constitutes the greatest item of repair expense?

O. C. BERRY:—I wish to comment on the advantage of the Knight engine as compared with the poppet-valve engine. I am not sure that the Knight engine is superior. The idea that a higher compression can be used in a Knight engine than in a poppet-valve engine is contrary to my experience. Has Mr. Green any special data to bear that out? Secondly, Mr. Green says that the spark-plug is better placed in a Knight engine than in a poppet-valve engine. From my way of looking at it, the spark-plug should be placed at the point where the mixture is richest. In the Knight engine the spark-plug is placed at the point of leanest mixture. This is a matter of considerable importance and seems to offset entirely the other obvious points of advantage. The best figures I have been able to obtain indicate just about equally good performance in the Knight engine and the poppet-valve engine.

HAROLD W. SLAUSON:—Were any tilting tests made to determine the relative stability of the pneumatic and solid tires of the same capacity?

CORNELIUS T. MYERS:—As people gain experience in any industry they accumulate not only a number of positive facts that are very valuable, but certain negative ones. In between the lines of Mr. Green's paper, in which appears the accumulated experience of many years, a lot of "don'ts" will be found. Mr. Green could serve us to a still greater extent if he would put down some of the big "don'ts" that are written down in his book of experience. There are many things that one should not do; these have been tried and found wanting. In that connection, they would be particularly valuable to executives, because executives of street-railway companies and those considering going into bus transportation of any kind must depend upon opinions that at times are not very reliable. The information may be given with all honesty and to the best of the ability of those concerned, but it does not have that reliability that is absolutely essential to the proper development of the motorbus business. The editor of *Railway Age* was inclined recently to be a trifle cynical in viewing the aspects of the rail bus. He said this rail bus appears in cycles of seven years' average and seems to be now in the fourth cycle. I think the discussion of his views showed very clearly that in the previous cycles the railroad men had to depend entirely on their own viewpoints and experience, simply taking the general broad idea of applying a gasoline engine to operating a rail car. If steam-railroad executives and street-railway executives who are considering this matter will call on the experience of the automotive industry, work with it and pay particular attention to the "don'ts" that are written in the books of experience of those who have been in this business, I think we shall have a comparatively rapid and a safe development.

ARTHUR J. SCAIFE:—Mr. Myers' remarks are similar to remarks made during the discussion on the subject of the rail motor-car which was entered into at the meeting of the Metropolitan Section of the Society held in New York City recently. With reference to Mr. Buckwalter's remarks, there was considerable prejudice against the motorbus, and especially on the part of the electric-railway companies. This, however, has disappeared within the last 2 years. The street railways have evidently come to the conclusion that it is much better to get into the bus business than to fight it.

I visited California recently and had opportunity to study the bus business. We have 400 to 500 buses or stages operating in that territory, a number of which are on long-distance work. They are all operating under franchises at present. This business started several years ago in a manner similar to that of a great many of the bus lines that operate today in the Eastern States. On long-distance work the Westerners are, I think, about 3 years ahead of us in the East. A few of the operators have bought up all the small franchises, so there are only about three large operators in California at present.

The buses operate at about 35 m.p.h., maximum. The average wheelbase is 200 in. Each bus carries from 18 to 25 passengers. The later models are equipped with 36 x 6-in. pneumatic front tires and 36 x 6-in. dual rear tires. The rear seat usually is located directly over the rear wheels, similar to passenger-car design. They have a seating space from 32 to 25 in. It is necessary to have ample room for comfort when carrying passengers from 126 to 500 miles. For instance, you can leave San Francisco at 8.00 a. m. and arrive in Los Angeles at 11.00 p. m., on the same stage, using three drivers.

I took a trip from Los Angeles to Bakersfield, a distance of 126 miles, the trip being made in 5 hr., which is an average speed of 25 m.p.h. This stage carries 18 passengers, has a four-speed transmission, with a maximum vehicle speed of 35 m.p.h. In going to Bakersfield we passed over three mountain ranges, having 1130 curves on the 29 miles of mountain; the maximum grade is 9 per cent and the average grade 6 per cent. They maintain a very good average speed over these ranges and around the curves, but if you are subject to sea-sickness do not ride in the back seat, as they say that nausea is very common when sitting there.

There is no doubt that motorbuses are coming to stay, but just what the ultimate bus will be for suburban, city or interurban work is a question that will have to be settled within the next 10 years.

R. E. PLIMPTON:—Mr. Green mentions an acceleration of 2 m.p.h. per sec. I think that applies mainly to buses of the cross-seat type and is too high for those with the longitudinal seats. For the latter 1½ m.p.h. per sec. is probably the maximum that should be used. At 2 or 2½ m.p.h. per sec. passengers are thrown toward the driver or to the rear of the vehicle when it is being started or stopped.

Mr. Cravens brought up the matter of double-deck buses for inter-city operation. Even in smaller towns the bus operators often find that the standard single-deck bus gives trouble because of trees or other obstructions. On long-distance work there are likely to be many obstacles of that sort, even though the traffic is sufficiently dense to warrant the double-deck vehicle.

G. A. GREEN:—Mr. Cravens asks if we have ascertained, as a result of our experiments, whether it is possible to reach a point where the center of gravity is too low; since, under such circumstances, excessive stresses would be imposed on wheels, bearings and springs, thus adversely affecting the riding properties and the main-

tenance costs generally. With the bus, from a low-level standpoint, ground-clearance is the limiting factor. With our L-type bus this has been cut down to 6 in., which we consider closely approaches the minimum. We do not believe a lower center of gravity is either necessary or desirable. With our design the riding properties can be considered as good, and, compared with our high-level equipment, there is no appreciable increase in maintenance costs. But vehicles with a low center of gravity do present many serious problems in regard to the side stresses mentioned. These problems are not at all easy of solution.

It is rather interesting to note that the appearance of a vehicle is subject to marked change as its height is decreased. A vehicle lower than our L-type bus gives an impression of a box formation and, consequently, the artistic value of the finished product is greatly lessened.

Answering Mr. Tarantous' questions, the $759.81 covering material used in connection with repairs to the chassis as per Table 5, naturally includes repairs and renewals to sleeves. The renewal of sleeves cannot be considered as particularly serious. They are not very expensive. They should last at least a year and their replacement is a comparatively simple matter.

With regard to the matter of fuel, standard gasoline as sold in New York City is employed exclusively by us. This gasoline meets the Navy Department's specifications.

Referring to Mr. Pfeiffer's query relative to gasoline ton-mileage with our L-type and J-type buses, since the same powerplant is employed in both cases, a marked difference is not to be expected. We do, however, obtain a somewhat better average with the J-type bus. Primarily, this is due to minor refinements in connection with the engine design. With regard to the matter of fuel-consumption expressed in terms of miles per gallon, in this respect the J-type bus shows a very marked improvement over the L-type bus. This, of course, is natural because of the lighter vehicle-weight and less number of passengers carried. As a rule, a single-deck bus is expected to accelerate more rapidly than a double-deck bus, and acceleration is very costly from the standpoint of fuel. In this connection it seems likely that the average builder and user of single-deck buses will be somewhat disappointed with his fuel-consumption figures.

In reply to Mr. Horine, a rear overhang of an abnormal length is certainly a hazard. It is clear that such construction necessitates particular skill on the part of the driver to clear obstacles when rounding corners. Another very serious matter is that of riding properties. Naturally, if the wheels are too far from the rear end, the passengers on the rear seats will be subject to considerable movement.

The danger of the outside stairway is more apparent than real. So far as my recollection goes, we have had only one or two accidents due to people falling from the stairway. In view of the fact that we have carried in excess of 300,000,000 passengers, the risk cannot be considered as particularly serious.

Large wheel-housings are unquestionably most unsatisfactory from the passengers' standpoint. Of course, the depth of the housings is automatically decreased due to the wide track and frame, the necessity for which is emphasized in my paper. In short, the outer edge of the tires should closely correspond to the extreme overall width of the body and the shape of the housings should conform as nearly as possible to the adjacent members such as brake-drums and the like. The best proposition appears to be a cast or pressed housing with rounded corners and an integral panel.

Regarding the necessity of a flat floor at the front end, this is desirable primarily to avoid accidents, since obstructions of any kind are liable to interfere with ingoing and outgoing passengers. In any event, the natural position for the driver's feet is in the horizontal plane.

Concerning comments on the clutch, a clutch brake is not employed in our service due to the fact that up to the present we have not been able to develop a satisfactory design. The conventional arrangement, while helpful when changing into higher speeds, is decidedly a deterrent when changing down. It must be admitted that many of our men are not expert in gearshifting; but it will be readily understood that we are extremely anxious to keep to our schedules; in short, to employ the highest possible safe speed. In considering that 1 per cent of lost time represents in round figures $16,000 in the form of wages and $50,000 as receipts annually, it will be recognized at once that some damage to the gearing is not extraordinarily serious. Lastly, it is our aim from the standpoint of design to provide everything that is essential but nothing that can be dispensed with, and the clutch brake naturally falls under this heading.

As to straight versus drop frames, our L-type bus has a kick-up at both the front and the rear; but the J-type bus has this at the rear only. We believe a double kick-up is necessary only for double-deck buses where the frame must be kept extraordinarily low. The double-deck bus is intended for operation on city pavements that are usually in fair condition. The single-deck bus is a utility vehicle; this class of vehicle will have a much wider use and therefore the matter of road-clearance must be taken into account. Of course, in many cases single-deck vehicles will be operated over very bad roads. In view of these facts it would seem bad policy to construct vehicles the frame design of which positively restricts their employment to certain localities.

Replying to Mr. Chase, as a result of many tests carried out to determine friction-horsepower losses in connection with various types of engine, we are satisfied that our Knight-type engine possesses remarkable properties in this respect. Table 1 gives figures representing an average of many tests which bring out this point clearly.

TABLE 1—FRICTION HORSEPOWER

Engine Speed, r.p.m.	Friction Horsepower
600	2.2
700	2.6
800	3.1
900	3.8
1,000	4.5

The fact of the matter is that with the poppet-valve engine a surprisingly large amount of power is consumed in connection with the operation of the valves and valve mechanism. In this connection it is suggested that builders of poppet-valve engines might gain something by studying this question even more closely in the future than they have studied it in the past. The best proposition is to carry out what we term progressive friction-horsepower tests. The thought is to check up electrically the power required to turn the engine over, starting first with the crankshaft in its bearings and then gradually adding the reciprocating parts, such as the valve mechanism, valves and the like.

Regarding the matter of design, insofar as our product is concerned, we can only say that we are building vehicles that have embodied in them many of the principles that we believe are essential to permit of safe, economical and

satisfactory operation. Of course, the design cannot be considered as perfect. From a motorbus standpoint the automotive industry is in its very early stages, and any design must of necessity be in some respects out-of-date even before its production could be commenced, assuming of course that there was no delay.

We realize that there are inherent advantages in other types of propulsion. I thoroughly agree with Mr. Chase that steam has wonderful possibilities. An entirely new field is opened in connection with the application of steam along automotive lines for the hauling of light loads on steel roadbeds. This point is drawn particularly to the attention of those who are enthusiastic in connection with the use of gasoline-propelled railroad-units. We recognize the merits of steam, but our entire organization has been trained along gasoline-usage lines. We therefore feel, at least at present, that we should concentrate our efforts on the development of the product with which we are most familiar.

Mr. Weaver has criticized my statement to the effect that the entire theory of design should be based on the highest safe vehicle-speed for the smallest throttle-opening and consequent minimum number of engine revolutions. His contention is that, under such conditions, the engine has a low volumetric-efficiency. Substantially Mr. Weaver is correct and possibly my remarks are somewhat misleading, but they are not intended to be taken too literally. As a result, in our service the throttles are sufficiently open to avoid the condition mentioned. About the only time they are almost closed is when the vehicles are at rest and the engines idling.

Mr. Bull has requested that a further analysis be made of Table 5 of my paper. He desires that the item of $759.81 for material used in repairs to chassis be subdivided, preferably under the various units. Obviously this will demand a considerable amount of study. In view of this, perhaps it will be considered sufficient to indicate the units in order of their importance from the standpoint of renewal and repair cost, as follows:

(1) Engine
(2) Transmission
(3) Brakes
(4) Clutch
(5) Rear Axle
(6) Front Axle
(7) Steering
(8) Radiator

Mr. Berry's queries are answered as follows: Regarding our contention that a higher compression can be used with the sleeve-type than with the poppet-valve engine, we feel this is due primarily to the absence of valve-pockets and the spherically shaped combustion-chamber. Our statements are based on numerous comparative tests that have been carried out in connection with our own service.

Regarding the center spark-plug location this may be incorrect theoretically, but we doubt it. As a matter of fact, we have accumulated an almost unique record from the standpoint of fuel economy. Our figures show consistent economy and are superior to anything we have been able to obtain with poppet-valve engines, regardless of the spark-plug location.

As to the matter of fuel economy, we average in excess of 7 miles per gal. with our double-deck buses throughout the year. With the single-deck vehicles we average from 10 to 11 miles per gal. Recently we sent a J-type bus to Philadelphia on a test run. The fuel average was 14½ miles per gal.; the speed average 22½ m.p.h. It was not necessary to add any water, and but 2 pints of oil was consumed.

If I understand Mr. Slauson's question correctly, he has asked whether we have made any tilting tests to compare the relative stability of vehicles equipped with pneumatic, semi-pneumatic or solid tires. All our tilting tests have been made with solid tires, but, of course, assuming wheels having the same diameter, we would not expect to find any difference in regard to stability.

The wisdom of preparing a series of "don'ts" such as was outlined by Mr. Myers appears somewhat debatable. Those interested in the construction or operation of buses unquestionably will be able to read between the lines of my paper, and sufficient information has been furnished to enable the acceptance or rejection of the various theories propounded. The power of suggestion is the thing that really counts and, according to my viewpoint, no man, regardless of his standing in the industry, should have the temerity to definitely state before the Society what it should or should not do. He should simply give his views, or, better still, the views of his organization and the reasons underlying them.

As to the utility of various forms of equipment, it would seem that any operation requires two types. In the majority of instances initial operation can profitably be commenced with single-deck vehicles; then, after the service is built up, double-deck buses should be added. Even after the service has reached a point where double-deck vehicles are required, the single-deck type will be found extremely valuable to aid in the natural process of development and for operation during cold and wet weather, or for all kinds of special service.

The Saurer Bevel-Gear Testing Machine

THE extraordinarily high standard of workmanship needed in gearing if it is to be silent, efficient and durable under the conditions of speed and loading that it is required to stand in modern design has made it necessary to devise machines capable of detecting the minutest want of accuracy. Only by such

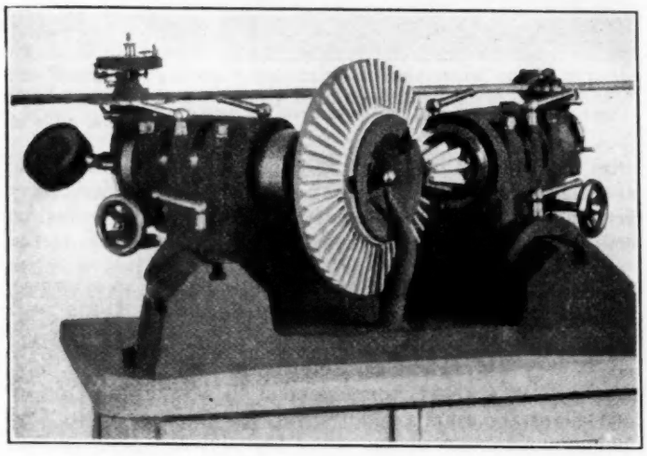

FIG. 1—GENERAL VIEW OF A MACHINE THAT HAS BEEN DEVELOPED FOR TESTING THE ACCURACY OF BEVEL GEARS

means can the necessary corrections to the finished gear be determined, and errors in the gear-cutting machines rendered noticeable in time to prevent a continuance of unsatisfactory work. In the case of bevel gears the possible errors are very numerous. The wheels may be distorted in shape, the tooth-forms may be incorrect, the teeth of irregular pitch, the pitch cones not in uniform contact and so on. The Société Anonyme Adolphe Saurer, of Arbon, Switzerland, which was manufacturing gears of very high class for use in its heavy motor vehicles, realized the necessity for some accurate and satisfactory method of testing the finished gears, and consequently devised for its own use machines for both spur and bevel gears.

The bed of the latter machine, as can be seen from Fig. 1, is a heavy, circular casting, upon which a pair of sliding heads can be locked in any position, so that the angle between the axes of the heads corresponds to that of the bevels to be tested, a range from 52 to 150 deg. being obtainable. A scale on the bed, provided with a vernier, allows this angle to be set with great accuracy. The wheels to be tested are mounted as shown. To check for the existence of bodily distortion of a wheel, the procedure is as follows. The large milled nut *a*, Fig. 2, at the back of the wheel is loosened, the wheel being then pressed forward by a spring so that its teeth go right home between the teeth of the bevel, which may be either a standard accurate pinion, or the mate of the wheel, as desired. The pinion is then rotated by the small handwheel *b* at the right end of Fig. 3. Any distortion of the wheel will cause the spindle of the latter to oscillate endwise. The motion of the end of the spindle is magnified by the pointer of the gage *c* shown at the left-hand of the machine in Figs. 2 and 3 and any irregu-

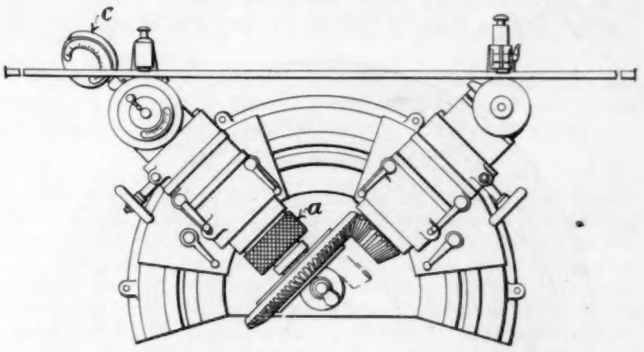

FIG. 2—VIEW LOOKING DOWN ON A PORTION OF THE MACHINE SHOWING THE RELATIVE POSITION OF THE VARIOUS PARTS

larity is clearly shown by the motion of the pointer on the scale, one division of which represents 0.01 mm. (0.03937 in.) of movement of the spindle.

To test for regularity of tooth-form and evenness of

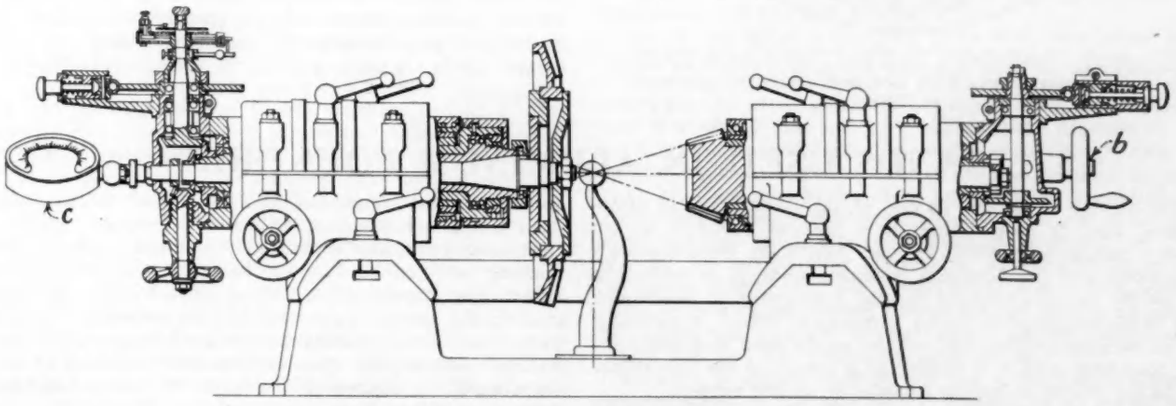

FIG. 3—ELEVATION PARTLY IN SECTION OF THE MACHINE

pitch, the wheels are set to mesh correctly. This is done by end-gages that determine the position of the spindles in the heads. Each spindle drives a vertical shaft at its outer end by a friction gear. The vertical shaft at the right-hand end of the machine carries a plain friction-disc outside the casing. The shaft at the other end of the machine is hollow and carries an indicating and recording instrument which rotates, of course, with it. Up the center of this hollow shaft is a fixed pin on the top of which is a circular table upon which the graphic records are drawn on charts. With this arrangement rotating either of the main gear spindles drives one friction-disc idly and rotates the indicating and recording instrument at the other end of the machine round the fixed chart. Under these conditions the pointer would remain stationary relative to its scale, and the pen would draw a circle on the chart. At the end of the machine that carries the instrument, there is, however, another friction-disc that can be rotated about the vertical spindle. These two friction-discs are coupled together by a rod at the back of the machine, the rod being kept pressed hard against their edges by spring-controlled rollers. The diameters of these friction-discs are so adjusted, in conjunction with the diameters of the friction bevels already mentioned, that the disc underneath the indicating and recording instrument would be driven at precisely the same speed as the instrument itself, if the speed-ratio of the bevels under test was absolutely constant.

A finger rotating with the latter disc is brought into contact with a stop on the instrument and is adjusted so that the pointer is moved to the center of its scale, and the pen also takes up its mean position on the chart. Any irregularity in the speed-ratio of the gears being tested, will cause the finger to move the pointer slightly as the two rotate together and will also cause the pen to move radially over the chart. Fig. 4 illustrates a chart drawn automatically in the manner described, by a pair of hardened bevel wheels made by the builder. The original chart was 3¼ in. in diameter, and the circles, 1 mm. (0.03937 in.) apart, corresponded to a magnification of 100 times the relative motion of the friction-discs. The wheels under test were a seven-tooth pinion gearing into a 55-tooth wheel, the pitch being 25 mm. (0.98425 in.) at the outer diameter. Such wheels are used for the rear-axle drive of the Saurer 5-ton truck with a 40-b.hp. engine, and in spite of the boldness of the design, it is stated that they have given excellent service.

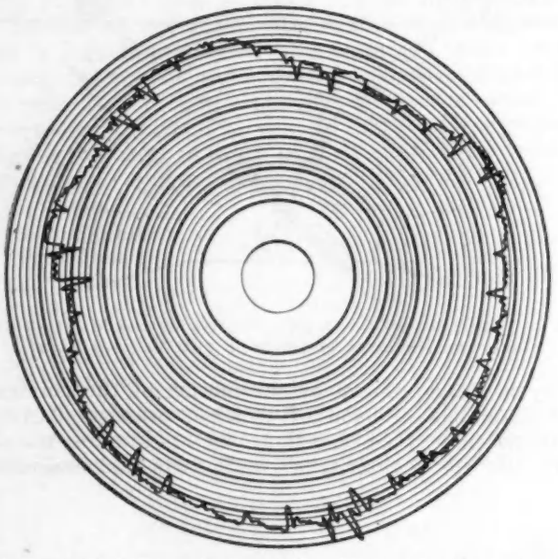

FIG. 4—A CHART MADE BY THE AUTOMATIC RECORDING MECHANISM OF THE MACHINE SHOWING VARIATIONS IN THE SPEED-RATIO OF A PAIR OF BEVEL GEARS UNDERGOING A TEST

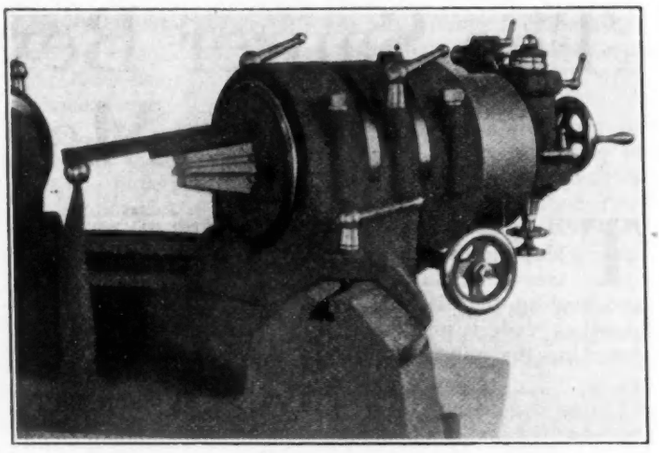

FIG. 5—THE MACHINE ARRANGED WITH A SPECIAL GAGE TO TEST THE ANGULARITY AND STRAIGHTNESS OF THE INDIVIDUAL TEETH

For testing the straightness and angularity of the individual teeth, the gage shown in Fig. 5 is employed. A ball-ended column fitting into a conical seat in the bed is permanently located so that the center of the ball coincides exactly with the intersection of the axes of any bevel gears that may be tested. A hardened steel gage has a conical cup near one end that fits over the ball, and a true straight-edge is formed along part of the side of the gage. The straight-edge points exactly to the center of the ball, so that by using the gage as indicated in the illustration any defect in the points or flanks of the teeth can be observed.

The operation of the machine is very simple and needs no more care or knowledge than a good tool-room mechanic would possess. It is specially intended for the testing of gear wheels for motor vehicles, and will take gears up to about 18 in. in diameter.—*Engineering* (London).

SANDS USED IN ALUMINUM FOUNDRIES

THE Bureau of Mines, as one of the Governmental agencies directly cooperating in a general research of all foundry sands, organized by the American Foundrymen's Association and the National Research Council, is collecting data on the sands employed for the production of molds and cores in aluminum-alloy foundry practice. There is pressing need of collated information on the sands used in aluminum-alloy founding, and it is hoped, as a result of the investigation, to aid in disseminating knowledge on the subject.

A questionnaire is being sent by the Bureau of Mines to aluminum-alloy foundries in the United States to obtain data for use in the preparation of a report. It is possible that some foundries of this kind are not upon the Bureau's mailing list, and it is hoped that any such plants failing to receive the questionnaire will apply for one. While the replies to the questionnaire will be summarized for publication, the contents of individual communications will be held strictly confidential. Communications in regard to the matter should be addressed to R. J. Anderson, metallurgist, Bureau of Mines Experiment Station, Pittsburgh.

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

GEARS[1]

NOISELESS gears are desirable chiefly from considerations of comfort. Nevertheless, since noise in gears indicates improper performance, improvement in quietness may represent a real gain in economy, especially in the change-gear sets and the rear-axle gears, where larger amounts of power are being transmitted. In the case of the accessory drives, which absorb relatively small quantities of power, this economy is of less moment, but here noise is even less tolerable.

Causes of Noise

Among the causes of noise in gears, the most obvious is the actual blow produced when one tooth becomes disengaged before the next tooth takes the load, a condition often found in the past when pinions with too few teeth were used. Inaccuracy in cutting is recognized at present as one of the most prolific sources of noise, but at times even accurately cut gears will become noisy for various reasons, such as, for instance, the misalignment that results from slight wear at the axle bearings.

Noise-producing factors, however, are to be found not only in mechanical effects, but are inherent, more or less, in the various geometrical gear layouts. Some of the variables affecting the amount of noise in theoretically correct gears are: (*a*) uniformity of pressure on the tooth surface and of load distribution between contiguous teeth; (*b*) ratio of sliding to rolling; and (*c*) relative sensitiveness to slight disturbances. For example, it is well known that helical bevel gears make for a quieter drive than do straight bevels, partly on account of the more uniform manner in which the former takes the load, the stub-tooth form is better than the ordinary involute as regards opportunity for interference, and cycloidal gears will hammer on very slight separation of the pitch circles.

It has been stated that resonance effects contribute not only to noisiness but also to excessive tooth pressure in gears. According to this idea a periodic torque impressed on the transmission system by any means, such as by periodic fluctuations of the engine torque, or by periodic errors in the cutting of the gears, will reinforce the natural torsional vibration of a gearshaft whenever the times of oscillation become equal to, or multiples of, each other. At those critical speeds of revolution where the resultant fluctuating tooth-pressure torque is equal to the transmitted torque, there will be a parting of the teeth and hence chattering.

No simple formula can be given for the elimination of noise. That the gear manufacturer is doing his share toward producing smoothly running gears is indicated by the increasing use that is being made of highly sensitive testing devices such as the Hartness optical comparator, recently described at the Buffalo convention of the American Gear Manufacturers' Association, and the Saurer gear-testing machine. The latter, an illustrated description of which appears elsewhere in this issue of THE JOURNAL, magnifies and records any difference in angular velocity shown by a pair of gears when compared with a pure rolling of their pitch circles.

As an example of how correct tooth layout may nevertheless lead to noisy gears, the treatment of interference given by Vessey and Seager may be cited, but the general question as to what produces noise in perfect gear teeth is still a subject of controversy, as is illustrated in the illuminating discussion brought out by S. Bramley-Moore's paper on Developments in Transmission read before the Institution of Automobile Engineers in 1920.

The resonance problem had no serious treatment until Dr. J. H. Smith attempted a mathematical analysis of the conditions under which forced vibrations are produced in gearsets. As a result of his final equations, Doctor Smith proposes, among others, a system of gear design called the "nodal drive," which possesses fewer of the critical speeds that give rise to noise and excessive stresses than does a haphazard assembly. A nodal drive, according to Doctor Smith's definition, is one in which the free periodicities of all the shafts, when considered as fixed at their gearbox extremities, are the same. A practical application of this system to the redesign of a set of double-reduction gears in the turbine-propelled ship Melmore Head, is reported by J. Wilkie as having been thoroughly successful. It would be interesting to extend Doctor Smith's analysis to the smaller but more complex gear assemblages used in the automotive industry, as it is probable that his method is capable of indicating what resonance effects are to be expected in this case.

Finally, attention may be directed to Neil MacCoull's attempt to determine the intensity of the sound emanating from a gearbox, and to correlate it with gear efficiency.

Mechanical Efficiency

The power lost in the several sets of gearing that constitute an essential part of automotive transmission and driving systems, is naturally a matter of much concern in this era of intensive study of the separate factors that might contribute to better performance. It is important to know, therefore, how much the mechanical efficiency of gears in general depends upon the choice of the lubricant, the method of lubrication, the speed and the load, and how the numerous varieties of design compare in regard to power loss. Other less pressing questions deal with the possible dependence of efficiency upon various other factors, such as, for example, the elastic and physical constants involved in Doctor Smith's description of the effect of torsional oscillations.

We have answers to very few of these questions; in fact, only the National Physical Laboratory is publishing regularly accurate results obtained by a systematic study of gears, but that work is at present limited to the question of the choice of lubricants.

One of the major difficulties to be overcome before satisfactory experimental data can be gathered, is the design of a testing machine that will prove adequate for indicating accurately the small efficiency variations involved. It seems that this would rule out any method that depends on subtracting the output from the input, even though this subtraction is done mechanically, as in the machine developed by C. M. Allen and F. W. Roys, and used by Heindlhofer for the testing of rear-axle worm drives. The electrical "load-back" scheme as a precision method, proposed by P. F. Walker for testing gear efficiencies, appears to suffer from the same defect. On the other hand, MacCoull's arrangement of double gearboxes represents an ingenious attempt to reduce the problem to the direct determination of the power loss and has promising possibilities.

Another proposed method for the direct-torque-difference determination of the mechanical efficiencies of gears is embodied in Wilfred Lewis's machine designed primarily for

[1] Concluded from THE JOURNAL, July 1922, p. 90.

testing the strength of gear teeth. However, only the preliminary work has been done with it, and it is not certain that it will be available for the important investigations on gear efficiencies that must be made in the near future.

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THE OSCILLOSCOPE IN THE STUDY OF MOVING MACHINE PARTS

A DISCUSSION is given in a recent number of *The Autocar*[1] of the possibilities of the portable Oscilloscope as an aid for the designer of automotive machinery, since it permits the exact study and measurement of the movements of machinery parts functioning at high speed. The principle of the apparatus consists of illuminating the moving object to be examined with a series of flashes from an electric lamp, arranged to take place at regularly spaced intervals in the movement of the part. In other words, it enables the eye to take a series of flashlight photographs in regular sequence and in such a way that the part appears to be moving at one-hundredth of the actual speed. By special adaptations of the instrument, it is claimed to be possible to analyze mechanical noises, to get the true periodicity of vibrations with relation to any given shaft without calculation, and to diagnose many of the ills from which engines and other chassis parts are apt to suffer.

[1] See *The Autocar*, March 4, 1922, p. 349.

Special Notice

TRANSACTIONS, PART I OF VOL. 16 (1921).

To Those Who Paid Dues for the First Half of the Fiscal Year Beginning Oct. 1, 1920:

The Council has directed that members shall be charged two dollars ($2) per Part of Transactions of the Society, beginning with Part I of Vol. 18 (1923). For further information on this matter see p. 261 of THE JOURNAL for April.

The two Parts of Vol. 16 (1921) and the two Parts of Vol. 17 (1922) will be sent, without charge in addition to payment of respective dues, to members on request, if request is received by the Society within 60 days from date of notice to order.

This is a notice to order Part I of 1921 Transactions.

The printing order will be based on the number of copies ordered by the members.

Copies cannot be guaranteed to members who do not order them on or before Sept. 30, 1922

If you want a copy of Part I of the 1921 Transactions please tear out and mail the coupon printed below promptly.

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The Standards Committee Meeting

THE action taken at the Standards Committee meeting at White Sulphur Springs, W. Va., on June 20, on the subjects reported by the several Divisions of the Standards Committee, is recorded below. After brief introductory remarks in opening the meeting and the declaration of a quorum by President B. B. Bachman, Standards Committee Chairman E. A. Johnston was introduced and called for the reports of the Divisions as printed in the June issue of THE JOURNAL, together with an additional report on Head-Lamp Illumination submitted by the Lighting Division. The action taken by the Standards Committee on the reports was submitted to the Council and the general business session of the Society on the same day and approved without changes.

The reports as given herein are for the information of the Members of the Society in casting their letter-ballots on the adoption of recommendations that were approved at White Sulphur Springs. This letter-ballot will close and be counted Saturday, Aug. 19, and should be returned by all Members prior to that date.

In every case the complete recommendation or a portion of it is printed below. For subjects that were approved as printed in the June issue of THE JOURNAL, the page reference to that issue only is given. For reports that were corrected, changed or amended, such changes are also given in this issue and should be noted in the reports published in the June JOURNAL. Section C44 of the Constitution of the Society reads as follows:

VOTE REQUIRED FOR ACTION

> Every question which shall come before a meeting of the Society or of the Council or of a committee, shall be decided by a majority of the votes cast, unless otherwise provided in the Constitution or By-Laws, or the Laws of the State of New York. The Council may order the submission of any question to the membership by letter-ballot. Any meeting of the Society at which a quorum is present may order the submission of any question to the membership by letter-ballot.

AGRICULTURAL POWER EQUIPMENT DIVISION REPORT

(1) TRACTOR DRAWBAR ADJUSTMENTS

The Agricultural Power Equipment Division recommends that the present S.A.E. Standard for Tractor Drawbar Adjustments, p. K40 of the S.A.E. HANDBOOK, be revised to conform with the limits specified in the table on p. 478

AXLE AND WHEELS DIVISION REPORT

(2) MOTOR-TRUCK FRONT-AXLE HUBS

The Axle and Wheels Division recommends that the tables on p. 476 be approved by the Standards Committee for adoption as an extension of the present S.A.E. Recommended Practice for Motor-Truck Front-Axle Hubs, p. F1b of the S.A.E. HANDBOOK

[This report was approved as printed on page 476 except that in the table under the caption General Information for Motor-Truck Front-Axle Hubs, the title under Spindle No. which read "Spindle Load Rating in Lb. on Solid Tire at Ground" was changed to read "Assumed Values on Which Calculations for Spindle Sizes Were Based."]

THE DISCUSSION

W. G. WALL:—With regard to the groove at the back end of the spindle thread, the width is given but not the depth. Is that assumed to be the same depth as the thread?

CORNELIUS T. MYERS:—No depth of groove is specified in the table. The groove is cut to an ordinary diameter so that the full thread can be run up to the shoulder. If it is thought advisable to specify the diameter, it can be included, but the usual practice is to have the bottom of the groove slightly below the bottom of the thread.

MR. WALL:—This is a detail. It is necessary that this groove be not too deep, but still deep enough that the thread can be cut without trouble. If the groove is made too deep, it simply weakens the end of the spindle.

CHAIRMAN E. A. JOHNSTON:—I think that is a very good point, as it is always desirable to specify dimensions in such cases; otherwise in purchasing material made outside, the undercut may be too deep.

MR. MYERS:—The stresses encountered at that point are so small that even if the usual depth of cut were doubled, it would not be of material difference. In a subsequent report the Division would be glad to submit a recommendation for practice, but we would like to have the present report approved.

PRESIDENT BACHMAN:—There is one point I would like to bring up for the information of the Standards Committee. It was the subject of some correspondence I have had with the Division with regard to the second part of the table dealing with General Information for Motor-Truck Front-Axle Hubs. It relates to the spindle load-rating. I have two thoughts on this particular proposition. One is personal, based on my feeling that the figures as they are given are not complete enough, and that if we want to consider giving such figures for general information, they ought to be extended.

I checked over one or two of them from a static load point of view only. As I recall, the result was a static-load stress of about 6500 lb. per sq. in., which seemed to be rather low. I did not attempt to take into mathematical consideration all of the stresses that would be imposed on the spindle from side-skids and other forces, as I have a certain amount of hesitancy in accepting mathematical results that are based on such premises.

The other matter is more of an official one. The Council has had called to its attention the desirability of formulating what may be called a motor-truck rating-formula, which in its essence would partake of the nature of the engine-rating formula which we know as the N. A. C. C. Horsepower Formula. I am inclined to feel that if anything can be done on that subject, we ought to know it within the next few months, certainly by the Annual Meeting next January. I am also inclined to feel that this particular recommendation as presented may have some complicating influence upon that work. Therefore, I would like to have considered the remarks I have made toward eliminating this portion of the proposed recommendation, including the dimensions, until we can

give it further consideration in whatever Division or Committee may be called upon to consider this other matter in conjunction with the Axle and Wheels Division.

MR. MYERS:—The point President Bachman has made is important. In connection with that, and his fear that anything printed in this report might be used in adverse legislation, I suggest, with reference to the second table, that instead of the title, "Spindle Load-Rating in Lb. on Solid Tire at Ground," the title "Assumptions on Which Calculations for Spindle Sizes Were Made" be used, so that there will be no basis for the figures being taken as definite load ratings. These values are to be published, not as standards or recommended practices; but as collateral data in connection with the work of this Division, which had a new problem to solve and wishes the basis on which it was worked out to be known.

In connection with the other matter that President Bachman mentioned, the Division thought it inadvisable to publish too many data at this time. The static load-ratings are low but, in the opinion of those who passed on this matter, they are not the controlling feature, whereas the dynamic side-skid ratings or stresses are. This was considered very carefully and the sizes were not based entirely upon calculations. The calculations were made so as to be able to compare one size with another and each with the practice as exemplified in the motor-truck industry.

When we had selected a series of sizes that seemed to meet with the approval of practically every one with whom we discussed it, the matter was taken up with the bearing manufacturers and slight modifications were made to use bearings of the most economical sizes.

No adverse criticism, to my knowledge, has come to the attention of the Division with reference to the sizes recommended, and the result of the work shows a considerable possible saving in the cost of bearings, on the basis of the loads selected.

The Division will, I believe, gladly present in detail at the next Annual Meeting the calculations and diagrams on which it based its recommendations. But approval of the work done to date is desired, if it can be put in such form as will meet Mr. Bachman's objections and any others that may be raised in the Council.

PRESIDENT BACHMAN:—The change that Mr. Myers suggests in nomenclature would meet the objection I raised. Possibly the description of the formulation of the report might be given fully at some time in the form of a paper or contributed discussion. I think some valuable work was done that will be of interest to many of the members.

ELECTRICAL EQUIPMENT DIVISION REPORT

(3) BREAKER-CONTACTS

The Electrical Equipment Division recommends for S.A.E. Recommended Practice that the hexagon-head of breaker-contacts and check-nuts shall be ¼ in. across flats and that the threads shall be No. 10-40

(4) IGNITION-DISTRIBUTOR MOUNTINGS

The Division recommends that the present S.A.E. Standard for Ignition-Distributor Mountings be revised by

(1) Specifying a dimension of 27/32 in. for the distance from the bottom of the distributor mounting barrel to the bottom of the tongue on the distributor half of the driving coupling of the Type-B ignition-distributor

(2) Changing the limits for the bore in the coupling from 0.4930 in. maximum and 0.4920 in. minimum to 0.4915 in. maximum and 0.4905 in. minimum

(5) MAGNETO MOUNTINGS

The Division recommends that the magneto dimensions given in the illustration on p. 477 be adopted as S.A.E. Recommended Practice, as an addition to the present S.A.E. Standard for Magneto Mountings, p. B14 of the S.A.E. HANDBOOK

THE DISCUSSION

F. W. ANDREW:—After collecting the data regarding the number of different magnetos installed in the service, covered by the recommendation, it was found that there were more than 50 different sets of mounting dimensions in use. Of the 50, the one that is recommended largely predominates. Rather than make an entirely new standard, we thought it was best to use this one.

(6) STARTING-MOTOR FLANGE MOUNTINGS

The Electrical Equipment Division recommends that dimensions "C," the diameter of the bolt-holes for sizes Nos. 1 and 2 of the S.A.E. Standard for Starting-Motor Flange Mountings, p. B19 of the S.A.E. HANDBOOK, be changed from 7/16 to 13/32 in.

ENGINE DIVISION REPORT

(7) FLYWHEEL HOUSINGS

The Engine Division recommends that the present S.A.E. Standard for Flywheel Housings, p. A1 of the S.A.E. HANDBOOK, be revised to specify that the clearance space for crankshaft flywheel bolts shall be 6½-in. minimum diameter and ¾-in. minimum depth

IRON AND STEEL DIVISION REPORT

(8) LEAF-SPRING STEEL

The Iron and Steel Division recommends the adoption of the specification on p. 480 for leaf-spring steel tolerances as S.A.E. Recommended Practice

(9) STEEL SPRING-WIRE

The Division recommends that the chemical compositions given in the table on p. 480 be adopted as S.A.E. Standard

[This report was approved as printed on page 480 of THE JOURNAL after deleting "for round, cold-drawn wire up to 3/16-in. diameter, except for some types of springs used in clutches, which are hot-rolled," in the paragraph immediately preceding the table, and the word "helical" in the caption of the table.]

THE DISCUSSION

MR. MYERS:—It seems to me that this specification might readily be given in the standard steel compositions with a note to the effect that it is suitable for helical springs, but I think it should not be called "Steel Wire for Helical Springs."

G. L. NORRIS:—I think that when this report is printed in the S. A. E. HANDBOOK it will appear among the standard steel compositions with a suggestion that it is suitable for helical springs. We do not recommend, as I understand it, steels for any purpose; but leave the application to the user.

G. S. CASE:—I have one suggestion as to the wording of the recommendation. The words ". . . except for some types of springs used in clutches, which are hot-rolled" are inappropriate because hot-rolled springs are not made of wire.

MR. NORRIS:—It may be drawn wire that is hot-coiled. Whether the report means "hot-coiled" is not clear. I believe it should read, "The Division recommends that

the chemical compositions given in the accompanying table be adopted as S. A. E. Standard for spring-wire."

MR. CASE:—That is all right.

MR. MYERS:—Not "for spring-wire." That should be in an accompanying note.

PRESIDENT BACHMAN:—I think that the sense of the meeting is clear. If the recommendation of the Division for Nos. 1350 and 1360 Steels be approved and the Division requested to frame a proper explanatory note, that will appear in the Iron and Steel Division's report but not as a part of the recommended practice, the purposes of the discussion will be fully served.

CHAIRMAN JOHNSTON:—I think what Mr. Bachman has in mind is that these steels can be used for many purposes.

MR. MYERS:—I will move the adoption of those two specifications to include only the composition of the steels.

LIGHTING DIVISION REPORT

(10) ELECTRIC INCANDESCENT LAMPS

The Lighting Division recommends that the G10, G12 and G16½ lamps be omitted from the S.A.E. Standard for Electric Incandescent Lamps, p. B3 of the S.A.E. HANDBOOK

(11) ELECTRIC INCANDESCENT LAMP VOLTAGE

The Lighting Division recommends that the present S.A.E. Standard for Electric Incandescent Lamp Voltages be revised by omitting the 8 to 10 and the 18 to 24 voltage-ranges and the reference to four and nine battery-cell arrangements

(12) HEAD-LAMP ILLUMINATION

Part 1—Laboratory Tests for Regulatory Purposes

Due to a rather complex situation that has arisen in connection with this subject, the Lighting Division was unable to make any definite report until after the June issue of THE JOURNAL was published, and the Division's recommendations on this subject are therefore printed in this issue.

The members of the Division feel that it is imperative that action by the Society by way of revision of the present S.A.E. Recommended Practice, p. B6 of the S.A.E. HANDBOOK, for Laboratory Test for Operating Requirements, be taken now inasmuch as such revision will lose its practical value if deferred until the January 1923 meeting of the Standards Committee.

At the meeting of the Lighting Division in November 1921 it was felt that the existing S.A.E. Recommended Practice should be revised in view of the improvements which had been made in motor-vehicle head-lamp equipment and lighting characteristics. A Subdivision was therefore appointed to cooperate in conducting tests which were then being made at the National Lamp Works of the General Electric Co. in Cleveland, and to report to the Lighting Division. While this work was progressing the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society prepared a report which was approved and published by that Society in February 1922. The Society's Subdivision, upon receiving this report, reviewed it carefully and subsequently reported its recommendations to the Lighting Division at its meeting on May 3, 1922. The Subdivision's report was the same as the published report of the Illuminating Engineering Society except that it included recommendations for two major changes and a few minor changes as a result of the tests that had been run.

The major changes that it was suggested be made in the Illuminating Engineering Society report were:

(1) The addition of a sentence under the paragraph "Requirements for Approval," that would specically state that in the case of different States having the same regulations, approval of a device by a specified laboratory test in one State may be accepted without further test by another State

(2) Under the paragraph "Approval," it was felt that the sentence "No device involving the use of a tilting reflector shall be approved unless it conforms with these specifications in its 'tilted-up' position and has an extreme tilting range of no more than 3 deg." would place an unwarrantable limitation on the development of controllable headlighting devices intended to furnish superior road illumination for operation under conditions where they can be safely used

The minor changes recommended were

(1) The Subdivision recommended that the italicized portion of the following sentence appearing under Test 1 for a pair of headlamps, should be omitted:
A pair of testing reflectors, mounted similarly to the head-lamps on a car, shall be set up in a dark-room at a distance of not less than 60 *nor more than* 100 *ft.* from a vertical white screen

(2) The substitution of *BL* and *BR* points for the *B* point on the diagram for test positions of the head-lamp beams in the Illuminating Engineering Society's report

(3) 2000 minimum cp. was recommended at point *A* in place of 1800 cp. in the Illuminating Engineering Society's report

(4) 7500 minimum cp. was substituted at points *BL* and *BR* in place of 7200 cp. at points 1 deg. to the left and to the right of *B* in the Illuminating Engineering Society's report. Points *BL* and *BR* are respectively 1 deg. each side of point *B* and are the same as the locations in the Illuminating Engineering Society's report

(5) Under the Test 2 for one head-lamp 2000 minimum cp. was proposed instead of 1800 at point *A* in the Illuminating Engineering Society's report

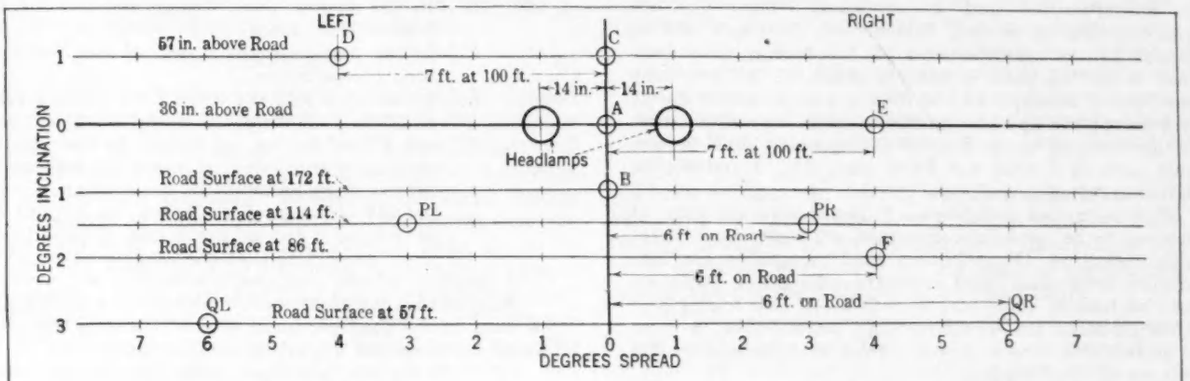
(6) A minimum of 3500 cp. was substituted for 3600 cp. at points *BL* and *BR* as described above

The Subdivision's report was discussed at length, the Division finally voting that since the Society and the Illuminating Engineering Society had cooperated in this work previously and as no opportunity had been had to consider the Illuminating Engineering Society's revised specification with the Illuminating Engineering Society Committee prior to its approval and publication by the Illuminating Engineering Society, the Illuminating Engineering Society Committee should be requested to hold a joint meeting with the Lighting Division for this purpose. The Division felt that but one specification should be approved by both Societies but that the changes noted above, particularly the major ones, were very desirable.

In the meantime a problem in connection with tail-lamp illumination was referred to the Illuminating Engineering Society by the Massachusetts State authorities and a joint meeting of the two Committees was called for and held on June 2. The situation with regard to headlighting specifications was also discussed at this meeting and it was voted that a letter ballot of the Illuminating Engineering Society Committee should be taken on the question of that committee reconsidering its report in view of the recommendation of the Lighting Division. Immediately thereafter the Lighting Division members held a meeting at which the following action was taken:

The Lighting Division appreciates the necessity for uniform laboratory testing specifications for motor-

SIDE GUIDE AND GRIPPER



1920 LIMITS.	
A-B	4800 cp Min.
C	2400 cp Max.
D	800 cp Min.
E-F	1200 cp Min.

1922 LIMITS.		
A	1800 cp Min.	6000 Max.
B	1° Right & Left	7200 Min.
C	800 cp Min.	2400 Max.
D		800 Max.
PL to PR		5000 Min.
QL to QR		2000 Min.

FIG. 1—DIAGRAM OF TEST POSITIONS

vehicle head-lamps as the basis for uniform State legislation but is strongly of the opinion that the modifications referred to above pertaining to "tilting devices," and the acceptance by one State of tests conducted in another, are of prime importance and should be agreed to by the two Societies

It was further voted to waive the suggested changes in measurements and candlepower values in the tests and to recommend for adoption as S.A.E. Recommended Practice the Illuminating Engineering Society revised specifications of February, 1922, provided the major modifications mentioned above should be approved by the Illuminating Engineering Society prior to June 20, 1922

It was also voted that if the Illuminating Engineering Society does not favorably consider the modifications advocated for the specifications, the Division recommend for adoption as S.A.E. Recommended Practice, to supersede the present S.A.E. Recommended Practice, p. B7, S.A.E. HANDBOOK the laboratory test procedure and numerical values set forth in the Illuminating Engineering Society revised specifications, and place itself on record as being opposed to the paragraph on "tilting devices" included in the said Illuminating Engineering Society specifications, and in favor of adding the sentence referring to acceptance by one State of tests made in another State

It was also decided that a definite report should be submitted for approval at the Standards Committee meeting on June 20 in accordance with the above action by the Division.

The Lighting Division thereupon recommended for adoption in revision of the present S.A.E. Recommended Practice on pp. B6 and B7 of the S.A.E. HANDBOOK, the accompanying specifications for the laboratory testing of motor-vehicle electric head-lamps. These specifications are taken from the Rules Governing the Approval of Headlighting Devices for Motor Vehicles, issued by the Illuminating Engineering Society and dated Feb. 9, 1922, and are intended to serve as the basis for legal requirements as to minimum road-illumination and maximum glare.

Part 2—Laboratory Tests for Desirable Illumination

At the same time that the Subdivision was studying the matter of regulatory laboratory-test specifications for motor-vehicle electric head-lamp illumination, it prepared a report on the laboratory determination of candlepower values to give the desirable amount of road illumination under normal operating conditions that would serve as the objective in designing and building head-lamps. Head-lamps conforming to the laboratory test under Part 2 of this report will conform to the regulatory laboratory-tests for minimum illumination and maximum glare specified in Part 1 of this report.

A report was submitted at the Lighting Division meeting of May 3 and approved as a specification separate and apart from that of Part 1 on the proposed laboratory tests for motor-vehicle electric head-lamps.

The points on the lighting chart referred to in the report are the same as those in Fig. 1 in the report for laboratory test specifications given in Part 1, with the exception that the *SL* and *SR* points are additional, as explained in the recommendation in Part 2.

The Lighting Division therefore recommends that the following proposal be adopted in revision of the present S.A.E. Recommended Practice for New Head-Lamp Equipment, p. B7 of the S.A.E. HANDBOOK:

	Candlepower Min.	Max.
A	2,000	6,000
B and intermediate points 1 deg. to right or left	25,000	....
C	800	2,400
D	.....	800
PL	10,000	....
PR	10,000	....
QL	4,000	8,000
QR	4,000	8,000
SL	500	....
SR	500	....

SL and *SR*—Four deg. of arc below the level of the lamps and 12 deg. of arc to the left and to the right respectively of the median plane

LABORATORY TESTS FOR MINIMUM ILLUMINATION AND MAXIMUM GLARE VALUES

(A) TEST OF DEVICES USED IN PAIRS

Samples for Test.—The samples submitted to the testing authority shall be representative of the device

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as manufactured and as marketed. They shall be accompanied by printed instructions for their use as issued by the manufacturer of the device. The samples submitted shall include as much of the accessory equipment peculiar to the device, except batteries, as is necessary to operate the device in its normal manner. In the case of front glasses the samples shall be one pair each of 8 5/32 (or Ford size) 8½, 9 and 9½-in. diameter when practicable.

Reflectors and Incandescent Lamps.—In the case of devices to be used in connection with standard parabolic reflectors, the reflectors used in making the laboratory tests shall be of standard high-grade manufacture of 1.25-in. focal length with clean and highly polished surfaces, and as nearly truly paraboloidal in form as practicable, and as approved for this purpose by the Bureau of Standards.

The incandescent lamps used in connection with the laboratory test shall be of standard manufacture and as approved for this purpose by the Bureau of Standards. In the case of devices involving the use of special incandescent lamps, such lamps, together with any necessary accessories, shall be submitted.

Marks of Identification.—Each device submitted must bear a distinctive designation prominently and permanently indicating the name and type of the device. Special incandescent lamps submitted in connection with devices shall bear the manufacturer's normal, clear-bulb rating.

Adjustment of Devices.—The testing authority shall adjust the device in accordance with the printed instructions issued by the manufacturer, which instructions must be adequate for practical purposes. An exact description of the adjustment made for test shall be given in the report.

Focal Adjustments of Incandescent Lamps.—The following designations of the focal adjustments of the incandescent lamp in the parabolic reflector are adopted:

Principal Focus. The beam, with bare reflector or plain front glass, is nearly parallel and of the smallest possible diameter

Rear Focus. The beam, with bare reflector or plain front glass, diverges as much as possible without having a dark center

Front Focus. The beam, with bare reflector or plain front glass, converges and crosses near the lamp and then diverges as much as possible without having a dark center

Special Focus. A special focal adjustment is allowed only when it can be clearly defined and described

Photometric Tests.—The tests shall be as follows:

TEST 1

A pair of testing reflectors, mounted similarly to the head-lamps on a car, shall be set up in a dark-room at a distance of not less than 60 nor more than 100 ft. from a vertical white screen. If a testing distance of 100 ft. is taken, the reflectors shall be set 28 in. apart from center to center, and if a shorter testing distance is taken, the distance between reflectors shall be proportionately reduced. The axes of the lamps shall be parallel and horizontal, or tilted in a vertical plane in accordance with manufacturer's adjustment. The intensity of the combined light shall then be measured with each pair of samples in turn, with the reflectors fitted with a pair of incandescent lamps of the gas-filled type, 6-8 volts, 21-cp. rating. The lamps shall be such as will give their rated candlepower when operated at their rated efficiency. They shall be operated at their rated candlepower.

Measurements shall be made at the following points at the surface of the screen:

A.—In the median vertical plane parallel to the lamp axes, on a level with the lamps

B.—In the median plane 1 deg. of arc below the level of the lamps

C.—In the median plane 1 deg. of arc above the level of the lamps

D.—4 deg. of arc to the left of the median plane and 1 deg. of arc above the level of the lamps

PL and *PR.*—1½ deg. of arc below the level of the lamps and 3 deg. of arc to the left and to the right respectively of the median plane

QL and *QR.*—3 deg. of arc below the level of the lamps and 6 deg. of arc to the left and to the right respectively of the median plane

A diagram of test positions is shown in Fig. 1.

All pairs of samples tested under the conditions prescribed above shall conform to the following specifications for observed apparent candlepower:

Point *A*, not less than 1800 cp. nor more than 6000 cp.

Point *B*, not less than 7200 cp., and there shall not be less than 7200 cp. at any point on the horizontal line through *B*, 1 deg to the left and to the right of *B*

Point *C*, not over 2400 cp., and not less than 800 cp.

Point *D*, not over 800 cp.

Points *PL* and *PR*, at each of these points and at every point on the line between them, not less than 5000 cp.

Points *QL* and *QR*, at each of these points and at every point on the line between them, not less than 2000 cp.

Note.—The above testing directions are drawn specifically to cover the case of devices accessory to parabolic reflectors of 1¼-in. focal length. In the case of other classes of [electric] devices where these directions evidently cannot be applied literally, their intent must be adhered to and the testing positions and candlepower limitations shall govern in all cases.

TEST 2

A single pair of samples taken as an average representative of the device as manufactured, shall be submitted to a complete test with the same testing equipment as specified for Test 1. This test shall show the light-distribution characteristics by actual measurements made in accordance with the best laboratory practice.

Distribution of Samples.—One pair of the samples submitted shall be retained at the testing laboratory for the purpose of future reference and as samples of construction.

(B) TESTS OF DEVICES USED SINGLY

Motorcycle head-lamps are used singly and not in pairs, and have commonly a reflector of smaller diameter and shorter focal length. Hence devices for use in connection with them are not included in the same classification as those for other motor-vehicles. For the laboratory tests of such devices two samples of representative sizes shall be submitted. They shall be tested with representative motorcycle head-lamp reflectors. The numerical limitations of apparent candlepower for Test 1 with one lamp only shall be as follows

Point *A*, not less than 1800 cp.

Point *B*, not less than 3600 cp., and there shall not be less than 3600 cp. at any point on the horizontal line through *B*, 1 deg. to the left and to the right of *B*

Point *C*, not more than 2400 cp.

Point *D*, not more than 800 cp.

Points *PL* and *PR*, at each of these points and at every point on the line between them, not less than 2500 cp.

Points *QL* and *QR*, at each of these points and at every point on the line between them, not less than 1000 cp.

Test 2 shall be made with one lamp and not with two.

Other deviations from the details of procedure are

obviously made necessary because of the fact that single devices instead of pairs are subjects of test.

THE DISCUSSION

L. C. PORTER:—With regard to the Lighting Division's report on Head-Lamp Illumination, I would say that the chief purpose of head-light regulation is, first, to prevent accidents, due to glare, and, second, to provide adequate lighting for night driving. To accomplish these things it is necessary to have specifications for lamps and reflectors that will regulate the projected light so as to prevent glare and to give adequate illumination where it is needed. Such specifications are worthless however if they are not enforced after they are drawn up. Therefore, to accomplish the ultimate object of both this Society and the Illuminating Engineering Society, the specifications as drawn up must be enforced by those who are in position to do so. These are the motor-vehicle administrators in the several States.

The Illuminating Engineering Society's headlight work, which has been under way for about 6 years, has been carried on primarily to assist the various State administrators in bringing about the conditions that I mentioned, safe and adequate driving illumination. Over 50 per cent of the cars in the United States and Canada have been operating under the old Illuminating Engineering Society specifications. The Headlight Committee has gradually won the confidence of the various administrators in the several States and has their backing in stiffening up the requirements. Naturally, it was necessary when this work was started, to begin with something that equipment on the market at that time could meet, and then gradually stiffen up the requirements.

A number of States have modeled their laws after the specifications that have been prepared. An association has been organized of motor-vehicle administrators representing the New England States, New York, New Jersey, Pennsylvania and Maryland.

In addition to the mechanical specifications that are printed in this report, the Illuminating Engineering Society has made certain other recommendations, largely at the request of the State administrators. I refer to the provisions given in the I.E.S. report under the captions "Reports" and "Approval," as follows:

> The report of the test shall be rendered in duplicate to the State authority and shall be signed or initialed not only by the expert making the test, but also by an executive officer of the institution making the test
>
> No device shall be approved which does not pass the laboratory tests
>
> No device involving the use of a tilting reflector shall be approved unless it conforms with these specifications in its "tilted up" position and has an extreme tilting range of no more than 3 deg.

The Division takes exception to the provision last given above. It seems to me that it involves largely legal administration. In the Eastern States where the roads are crowded and not very mountainous, and there are not many curves, probably a headlight that can be tilted up is a dangerous thing. The administrators in those States certainly feel that it embarrasses them in enforcing their regulations. On the other hand, in the Middle West and in the Western States, in the mountainous districts, headlights that can be tilted up are certainly a good thing. It seems to me, therefore, that the subject-matter of the clause in question should be left to the different State administrators, as provided for in the next clause which reads:

> The State authority reserves the right to refuse approval of any device which in his opinion is liable for any reason to prove unsafe or unsatisfactory in practice. Among the defects that may cause rejection under the above rules are unnecessary loss of light due to absorption or diffusion; abnormal or unduly complicated adjustment; unstable or bad mechanical construction; unduly bright or dark areas or excessive contrast in the illuminated field; irregular or badly defined cut-off line

There is another clause, entitled Alterations in Design, that has been found in practice to assist very materially laboratories in making tests and administrators in recognizing equipment on the road as equipment that has or has not been approved by the State:

> In case the design or construction of any device is changed in any way that alters the characteristics by which it is ordinarily identified, a new name or type designation must be given and the device may then be submitted for approval on the same basis as a new device
>
> An alteration in the design of an approved device that does not affect its distinctive appearance, but is made for the purpose of improving its performance, or to correct for alterations made in the standards of construction of incandescent lamps or reflectors, may be allowed under the original approval of such device, provided due notice of such alteration is given to the State authority and verification tests satisfactory to the State authority are made, which show that the device as altered complies with these specifications

I think that is a very good provision.

There is one more paragraph on Verification Tests, which reads:

> As a safeguard against deviations of the design and construction of an approved device from that on which approval was originally based, the State authority reserves the right to submit from time to time samples of approved devices to the testing authority for a verification of their performance, or to require the submission at suitable intervals of certified copies of reports of such verification tests satisfactory to the State authority made by a person or an organization fulfilling the requirements of a testing authority. In case copies of verification tests are not submitted as required, or the verification test shows failure of any device to conform to the specifications, the State authority may suspend or withdraw approval of such device

That seems to be a proper provision because in making lenses, for example, the molds wear and the lenses may change so much that they do not give the distribution of light that the original lenses that were submitted for approval gave.

I would like to move that that portion of the Illuminating Engineering Society's report which is presented in the Lighting Division's report be approved as S.A.E. Recommended Practice, and that the Standards Committee endorse that portion of the Illuminating Engineering Society's report entitled "Reports" and "Approval," with the exception of Par. 2 under "Approval," which reads: "No device involving the use of a tilting reflector shall be approved unless it conforms with these specifications in its tilted up position and has an extreme tilting range of no more than 3 deg."; and also adding a clause giving one State authority to accept tests conducted in another State.

C. A. MICHEL:—With regard to stating specifically that one State may accept another State's tests for the approval of a device, I would say that at the present time an outlay of approximately $1,500 is required to get the approval of a device throughout the Country; involving a number of hand-made samples in some instances, because a manufacturer must have his device approved before he can go into regular production. The testing

fees mount up so rapidly that it is imperative to have a clause of that kind to encourage making improvements in devices.

PRESIDENT BACHMAN:—I think that the motion is too complex. I would prefer to vote on parts into which it might be divided. We have two things under consideration: the adoption of specifications of numerical values, etc., that properly can be interpreted as S.A.E. Standards of a technical nature; and the endorsement by the Society of acceptance tests and other matters which in my estimation partake somewhat of politics and on which the Society would do well not to commit itself. I am not at all sure that the constitutional restrictions of the Society are effective in this particular case. I am inclined to believe it is dangerously close to the borderline. While I appreciate thoroughly what Mr. Porter and Mr. Michel have said and some of the State administrators have taken up this question with me, I am very strongly of the opinion that we would go outside of our legitimate field if we endeavored to draft laws.

I do not underestimate the conditions under which the States are operating in their endeavor to equalize the use of the highways among all people and to safeguard the rights of the citizens who use the highways. I think that in approving technical values upon which tests may be based we will go as far as we can. To go beyond that, attempting to outline methods of legal enforcement or of administration, is outside of our province.

MR. CRANE:—I had more or less to do with this headlight illumination question about 2 years ago, when the attempt to assign numerical values over a considerable field of illumination was first made. This was evidently a move in the right direction. On the other hand, it has become plainer every day that we must compromise. We know that there is no really good driving illumination that is not glaring in some positions. We have taken the best averages that we could, illuminating as strongly as possible where it can be done safely, and toning the illumination down where it is apt to reach the eye of an approaching car driver.

I think that the Society should stop at what it considers to be the best compromise covering these conditions. The Society should not take action in the Standards Committee on the question of adjustable or non-adjustable headlights. That is a question partly of engineering practice and partly of state administration. We all know that the standard head-lamp in the standard adjusted and fixed position does not give a thoroughly good driving light; and I am sure that we do not want to take the position that the driver should be permitted to vary his head-lamps from a normal condition when he wants to. I have seen too much in my own driving of the misuse of apparatus permitting this, although much of it is unintentional. The driver has nothing to show him when he is within the law and when he is not, and he puts his device into a pretty good position as far as he is concerned from a driving point of view, and lets it go at that.

With regard to the Division's report, I would like to move, Mr. Porter's motion not having been seconded, the adoption of the specifications as outlined covering only safe illumination, and eliminating all extraneous matters pertaining to application, methods of administration or approval of adjustable head-lamps as against non-adjustable head-lamps.

CHAIRMAN JOHNSTON:—Mr. Crane's motion is in effect to adopt Part 1 of the Lighting Division's Report on Head-Lamp Illumination.

[The motion was seconded by H. W. Alden.]

OSCAR F. OSTBY:—The acetylene interests were drawn into this headlighting matter because the specifications did not include all types of head-lamp. The tentative rules and regulations, as laid down by the Illuminating Engineering Society, as you probably know, were sent to the various States and used as a basis for State legislation. All of the States in which we have had the privilege of presenting our side of the story have made exceptions to the rules and regulations as laid down by the Illuminating Engineering Society.

I believe that the test of any specification is its practical application under operating conditions, and that rules and regulations that do not work out under practical operating conditions should not be endorsed by such a prominent organization as the Society of Automotive Engineers. I will refer to the State of Massachusetts, the last State that passed a headlight law under the Illuminating Engineering Society's specifications. We did not know that the proposition had gone as far as it had. I went to Boston and found that a temporary list of approved devices was about to be issued under the Massachusetts law, which was based absolutely on the Illuminating Engineering Society's specifications. I called on Frank Goodwin, the registrar of motor vehicles, told him that I represented the acetylene interests, and presented my case. Among other things I called his attention to the fact that there are as many acetylene head-lamps used on motor trucks today as there were on passenger cars in 1910 and 1911, and that most of the motor trucks operating in Massachusetts could not possibly comply with the proposed regulations.

As the result of a pretty thorough investigation, in which the motor-truck people in Massachusetts were just as much interested as we were, Mr. Goodwin's office made an exception for acetylene head-lamps and issued a temporary approval, which has since been made permanent; for acetylene head-lamps equipped with a $\frac{5}{8}$-ft. burner, 6-in. spherical mirror, and a clear glass front, which produces the necessary 2100 cp. called for by the law. In other words, so-called non-glare lenses are not required for acetylene head-lamps because it was found under practical conditions that they are entirely unnecessary.

Any specification or law that does not contemplate practical operating conditions does not belong in statute books. We have had to contend with this proposition everywhere that it has appeared because it has been misconstrued by State legislators to include acetylene head-lamp illumination. State legislators are not well posted on light, electric lighting and road illumination, and for that reason these specifications have been accepted as head-lamp regulations, with no classification as to the nature of the source of light.

MR. R. S. BURNETT:—This was one of the points considered by the Lighting Division in preparing its report, which is presented for approval as applying only to motor-vehicle electric head-lamps, and, if adopted by the Society, will be so published.

CHAIRMAN JOHNSTON:—We have before us a motion, duly seconded, to approve Part 1 of the Lighting Division's Report on Head-Lamp Illumination as submitted.

[The motion was carried.]

MR. MICHEL:—Part 2 of the Division's report is not a part of the Illuminating Engineering Society's report. Part 1 gives values for legal minimum illumination and maximum glare, while Part 2 gives values for desirable driving light. Head-lamps which comply with the specifications given in Part 2 will comply with the tests specified in Part 1.

CHAIRMAN JOHNSTON:—Is there any further discussion with reference to Part 2 of this report?

MR. PORTER:—I move that it be approved.

[The motion was duly seconded and carried.]

(13) HEAD-LAMPS

The Lighting Division recommends that the present S.A.E. Recommended Practice for Head-lamps, page B1 of the S.A.E. HANDBOOK, be revised as indicated on p. 480.

(14) MOTORBOAT LIGHTING VOLTAGES

The Lighting Division recommends that the accompanying report submitted by the Subdivision be adopted as S. A. E. Recommended Practice.

(1) For motorboats and small cruisers having combined starting and lighting equipment, it is recommended that nominal 6-volt (6 to 8 volts) or nominal 12-volt (12 to 16 volts) systems be used

(2) For larger cruisers having separate lighting equipment, it is recommended that the 32 or 110-volt system be used

NON-FERROUS METALS DIVISION REPORT

(15) ALUMINUM ALLOYS

The Non-Ferrous Metals Division recommends that Specification No. 34 given on p. 481 be adopted as S.A.E. Standard.

THE DISCUSSION

CHARLES PACK:—This specification was written at the request particularly of D. L. Gallup, formerly of the Nordyke & Marmon Co. Dr. Zay Jeffries, who submitted the specification, stated that about 95 per cent of the aluminum pistons used in automotive construction are made to it. A number of other alloys were submitted but I believe that the specification given surely represents major practice in the automotive industry.

(16) WHITE BEARING METALS

The Division recommends the adoption of the extended specifications for White Bearing Metals Nos. 11, 12, 13 and 14 given on p. 484.

[Specification No. 10 on p. 484 was approved as printed except that the tin-content was changed to 90.75 per cent minimum for ingots and 90.00 per cent minimum for cast products.

Specification No. 11 on p. 484 was approved as printed, except that the tin-content was changed to 86.00 per cent minimum for cast products and 87.25 per cent minimum for ingots.

Specification No. 12 was approved after adding a tin-content of 59.50 per cent minimum for cast products and 60.00 per cent minimum for ingots and changing the lead-content for cast products to 26.00 per cent maximum and for ingots to 25.25 per cent maximum.

Specification No. 13 was a misprint in THE JOURNAL on p. 484 and was approved as follows:

	Cast Products	Ingots
Tin	4.50 to 5.50	4.75 to 5.25
Antimony	9.25 to 10.75	9.75 to 10.25
Lead, Max.	86.00	85.50
Copper, Max.	0.50	0.50

Specification No. 14 was approved as printed on p. 484, except that the lead-content was changed to 76.00 per cent maximum for cast products and 75.25 per cent maximum for ingots.]

THE DISCUSSION

MR. PACK:—I would like to point out that the recommendations here given are somewhat of a departure from the usual methods of specifying alloys. I would also like to mention the fact that we have only extended and not changed the present S.A.E. Specifications Nos. 10, 11, 12, 13 and 14, for babbitts. We found in practice that automotive plants generally purchase ingots or finished bearings. The present standards cover finished products very well, but in purchasing ingot metals for the purpose of fabricating bearings it is not possible to maintain the S.A.E. Standard in the finished product. For example, in the case of S.A.E. Babbitt No. 11 the producer of the ingot has a tolerance of plus or minus ½ per cent in the tin-content. It is customary for the ingot manufacturer to take all the leeway he can on the tin-content, it being the most expensive element in the alloy. The possibilities are that he will produce an ingot containing 87.1 per cent of tin, with the result that the automotive manufacturer who uses that ingot for producing bearings will have only 0.1-per cent leeway before he gets below the specified tin-content.

It was therefore thought advisable, and it is in accord with the practice in some of the larger automotive plants, to establish another set of specifications for ingots, allowing the present specifications for babbitts to stand for finished products or, as we call them, cast products. It will be noticed that in every case we have kept within the mean of the tolerances permitted in the present specifications, but holding the limits much closer on the ingot, which is also in accordance with good practice.

After these specifications were originally adopted, the Division felt that the tin should not be specified with maximum and minimum limits, but that a minimum only should be established.

(17) WROUGHT NON-FERROUS ALLOYS

The Non-Ferrous Metals Division recommends that Specifications Nos. 77, 78, 82 and 83 given on pp. 482 and 483 be adopted as S.A.E. Standard.

[The caption for Specification No. 77 (see p. 482) was changed from "Phosphor Brass Strip for Flat Springs" to "Phosphor Brass Strip." Specification No. 78 was approved as printed on p. 482 and Specification No. 82 was approved as printed on p. 483 after changing the caption from "Brass Wire for Brazing" to "Brass Wire" and adding the words "brazing and" before "torch welding" under General Information White Bearing Metals.]

THE DISCUSSION

MR. PACK:—In drawing up Specification No. 77 for phosphor-bronze strip for flat springs the Division tried to adhere as closely as possible to the American Society for Testing Materials specifications, which has been the practice in the past. It was felt however that the American Society for Testing Materials specifications should be abridged somewhat so as to bring them more into conformity with the general practice of this Society. Specification No. 78 also was drafted by Dr. Jeffries and carefully discussed at the meeting held in May. Here also American Society for Testing Materials practice was followed, but omitting some unnecessary features from the Society of Automotive Engineers standpoint. I believe that these specifications represent the best practice in the aluminum-sheet industry.

The Society has adopted a brazing wire, I believe, by previous action. The Division now submits a specification for wire for brazing, given in Specification No. 82. Under General Information, it is stated that wire in accordance with this specification is suitable for torch welding.

MR. MYERS:—I offer the same objection in this case as in that of the steel wire specifications; the purpose for which this wire is intended is specified.

MR. PACK:—The purpose for which this wire is intended also appears under General Information. If you will refer back to the piston-alloy report, you will find a note that

This alloy cast in permanent molds is used principally for pistons, camshaft bearings, valve-tappet guides and other parts where high hardness and good bearing qualities are essential.

The Division felt that this is a similar type of specification and I believe that this particular alloy is well recognized as a brazing metal only.

MR. MYERS:—I have no objection to that, but I think that the caption referring to brazing ought to be removed.

MR. PACK:—I think this is largely a matter of policy and if it is the policy of the Standards Committee to omit such references in captions, I see no objection to removing the words "for brazing" and having the heading read "Brass Wire."

C. M. MANLY:—It seems to me that we are discussing a number of technicalities. If we print a lot of specifications and almost conceal what they are meant for, it looks as though we are afraid of what we are doing. If this brass wire is only good for brazing, why classify it as a general composition, and state somewhere in a footnote what it is really intended for, and make the getting of information from the S.A.E. HANDBOOK all the more difficult? We ought to stand on our feet in these matters and state what we mean.

In connection with "Phosphor Strip for Flat Springs," why flat springs? But if that is what the specification is intended for, let us say so. I did not raise any objection in that case because it seemed to me the Division has said what it meant. It seems to me the Division has said what it means regarding wire for brazing. I do not believe this is in any way breaking down our system in the Society's standardization work. We are, of course, trying to keep away from standardizing design and placing too close limitations through standard specifications; but on the other hand, if we are going to render the greatest benefit in this work, let us say what we mean.

MR. PACK:—These specifications, particularly the one for brass wire for brazing, were the direct result of requests from automotive manufacturers, including one for a wire suitable for brazing that is considered standard practice in the brass mills. Mr. Bassett, Mr. Price, and Mr. Webster, members of the Sub-Division, recommended this wire as especially suited for brazing. It may possibly have other uses, but the object of the Division in preparing this specification was to recommend a good brazing wire.

MR. CRANE:—The fact that under General Information it is stated that "This is also suitable for torch welding," indicates that it is not exclusively a brazing wire. I like to see the S.A.E. HANDBOOK of uniform style. There ought to be uniformity in presenting the information. In this case I would like to see the specification presented as for "Brass Wire," and in the General Information a note that "Wire in accordance with these specifications is suitable for brazing or torch welding."

MR. PACK:—Before this change is acted upon, would it not be well to reconsider the approval of Specification No. 77? We seem to have passed over that entirely without having had the same criticism as has been had on the Brass Wire for Brazing.

MR. CRANE:—We should use good form in presenting all such information in the S.A.E. HANDBOOK, purely as a matter of style, and for ease of consultation. We have the same thing with regard to White Bearing Metals. In each case there is a specification number, a general name for the metal and general information as to what it is useful for. I think that is an excellent form to follow.

PRESIDENT BACHMAN:—My thought in the matter is that this is largely a matter of captions. The value of the specifications is not lost by omitting reference to their purposes from the titles and putting it in notes under General Information. It is only an indication of how we want the information presented.

MR. PACK:—I believe President Bachman's point is a good one. It is a matter of general policy rather than of particular specifications.

CHAIRMAN JOHNSTON:—It seems to me that the Council could rule on some phraseology for all such cases, if it is permissible to pass these standards here and revise the phraseology later.

PRESIDENT BACHMAN:—I think that a general motion indicating the sense of the meeting as an instruction to the Standards Department would settle the whole matter. I move that the Standards Department be instructed to withhold from the caption and the body of these proposed standards any direct reference to the usage of the material, and that all such information be embodied in a footnote, in the form of General Information.

[The motion was seconded by Mr. Myers and unanimously carried.]

PARTS AND FITTINGS DIVISION REPORT

(18) BALL STUDS

The Parts and Fittings Division recommends that the dimensions for ball studs specified on p. 487 be adopted as S.A.E. Recommended Practice.

THE DISCUSSION

F. G. WHITTINGTON:—After a considerable amount of work this subject was presented at the Summer Meeting in 1921, at which time criticisms were made indicating that further work should be done. It was therefore referred back to the Division for further consideration. These criticisms proved to be very constructive and by serious consideration of them the Division has formulated what is believed to be a satisfactory recommendation. In augmenting the report of 1 year ago, we have extended the sizes to include smaller and larger ones than the five in general commercial use.

One criticism at the meeting a year ago regarding the ball size indicated the advisability of making the ball smaller than the normal size for two reasons, lubrication and manufacture. A tangential condition between the seat and the ball adds very materially to the lubrication factor, and obtaining this condition by both the ball and the seat being spherical, but of different sizes, avoids a bad machining job to provide a tangential effect by other means. Another good reason for undersize balls is that they can be made from standard instead of oversize stock, and standard drills and reamers can be used for the sockets.

Accordingly the Division has incorporated the undersize balls in the recommendation, varying the amount of undersize with the size of ball in three stages:

1/64 in. undersize on ½ to ⅞-in. sizes inclusive
1/32 in. undersize on 1 to 1¾-in. sizes inclusive
1/16 in. undersize on 2 to 3-in. sizes inclusive

Another criticism in 1921 was as to the amount of angular motion due to the shape of the neck. The dimensions recommended are such that the theoretical strengths of all the studs are proportional to their ball surfaces and they allow angular movement of the drag-links of 10 deg. in either direction.

The taper shank is of such length as to give a grip on the forging about equal to the large diameter of the shank and has a taper of 1½ in. per ft.

The thread is arranged to provide space for the lead of the chasers to run out. This space, equal to three

threads, is one regarding which there has been much misunderstanding. It is not an allowance for drawing the stud tight in its seat, which must be additional and sufficient to cover unavoidable manufacturing variations in the diameter of the shank and reamed hole, which will total from plus 0.003 to plus 0.005 in. The required allowance for draw is from 3/64 to 5/64 in. This deals with studs with good screw-machine finish, hardened and brushed to remove scale. Studs finished by grinding would, of course, have allowances much less than the figures given.

The nut to be used is a slotted nut of S.A.E. Standard dimensions, not a castled nut.

There is also shown on this stud a straight diameter extending from the large end of the taper toward the ball, to provide better fitting surface for dust-boots.

(19) Lock-Washers

The Parts and Fittings Division recommends that the present S.A.E. Standard, p. C5 of the S.A.E. Handbook, be extended to include the temper and toughness tests given on p. 524.

(20) Passenger-Car Front Bumpers

The Division recommends that the passenger-car front-bumper mounting shown in the illustration on p. 485 be adopted as an extension of the present S.A.E. Recommended Practice for Passenger-Car Front Bumpers, p. C55 of the S.A.E. Handbook.

THE DISCUSSION

Mr. Whittington:—I wish to augment the printed report by saying that the Division fully realizes there are some cars on which the mountings cannot be made as shown in the recommendations, but such a condition cannot be avoided. The fact that 90 per cent of the car builders approved such a recommendation clearly shows there is no reason why this recommendation cannot be approved. In connection with the present standard, the Division decided in working on the bumper mountings at this time to deal strictly with the mounting and avoid any discussion of the existing standard as to bumper dimensions. We realize that general bumper practice now makes the present standard of little value and we intend later, after the mounting feature is finished, to consider revision of the present standard, and not to confuse the work at this time.

(21) Plain Steel Washers

The Parts and Fittings Division recommends for adoption as S.A.E. Standard the table of plain steel washers given on p. 485.

(22) Serrated Shaft Fittings

The Parts and Fittings Division recommends that the taper and straight shaft-serrations shown in the illustrations and tables on pp. 488 and 489 be adopted as S.A.E. Recommended Practice for Serrated Shaft Fittings.

THE DISCUSSION

Mr. Whittington:—The work on serrated-shaft fittings has met with many delays, but has finally been brought to a form that the Division feels is sufficiently definite and complete to allow of its presentation to the Standards Committee for approval.

Considering first the straight serrated-shaft fittings, we found less tendency toward any standard among manufacturers than in the tapered fittings, but in drawing up our recommendations we have avoided conflicting with present practice as much as possible. The straight fittings are intended primarily for carrying strains in one direction. The selection of the number of serrations is important, as there must be enough to provide for ample adjustability but not so many as to cause manufacturing difficulties. Finding little uniformity in practice, the Division has selected 36 serrations on sizes 1/8 to 5/8 in. inclusive and 48 on 3/4 to 3 in. inclusive. This gives ample adjustability and affords easy indexing for machining.

With regard to tapered serrated-shaft fittings, we find a greater tendency toward uniformity and have accepted current practices as far as possible in our recommendations. Tapered-shaft fittings are intended for reversible strain loads, and are recommended in sizes from 1/2 to 3 in. inclusive; no sizes being specified below 1/2 in., as these are not used. The teeth on the taper fitting have practically uniform width of flat on top and bottom throughout their length. The number of serrations selected corresponds closely to present practice; 36 serrations for 1/2 to 1 3/4 in. inclusive, and 48 serrations on 2 to 3 in. inclusive. The taper is 3/4 in. per ft. on the outside diameter. The cutting angle is 1 deg. 37 min.

(23) Rod-Ends

The Parts and Fittings Division recommends that the present S.A.E. Standard for Rod-Ends, p. C8 of the S.A.E. Handbook, be extended by the addition of a 1/2-in. rod-end with a length of 3 in.

THE DISCUSSION

President Bachman:—It has always seemed to me that truck requirements have not been properly taken care of in considering these standards for rod-ends, clevis-pins and yoke-ends. Trucks equipped with solid tires and in which there is much vibration, offer a big field for a yoke-end having a larger pin than is required by any consideration of strength, both in diameter and in length of bearing, which will not wear so rapidly. That is one of the reasons I have never felt that this was a standard that we could use in our own product.

Mr. Whittington:—Is it your idea, Mr. Bachman, that we should have even heavier sizes than given in the heavy series?

President Bachman:—I think that the heavy series as listed here would probably have small usage on passenger cars, and for the reason I have indicated it is not satisfactory for trucks.

Mr. Burnett:—The Standards Department referred this subject to all the companies that we found were making these forgings and I believe they were all satisfied with the standards as they are, with this one change that is now recommended. There was a little difference of opinion regarding the 1/2-inch size, but apparently from the information we got from the forging manufacturers they have been furnishing and stocking these standard fittings for some time to the trade's satisfaction.

(24) Tank and Radiator Caps

The Parts and Fittings Division recommends that the present S.A.E. Recommended Practice for Tank and Radiator Caps, p. C58 of the S.A.E. Handbook, be extended by adding the note, "It is recommended that on passenger-cars, motor-trucks and tractors gasoline-tank filler-pipes have a minimum clear opening of 2 in. in diameter."

PASSENGER-CAR BODY DIVISION REPORT

(25) Top-Irons

The Passenger-Car Body Division recommends for S.A.E. Recommended Practice that the threaded-end of top-irons shall be 7/16 in.—14 U. S. S. with a 5/8-in. length of usable thread and a 1-in. length of stud.

SCREW THREADS DIVISION REPORT

(26) Screw Threads

The Screw Threads Division recommends that the

present S.A.E. Standard for Screw-Threads, p. C1 of the S.A.E. HANDBOOK, be extended to include the tables and definitions given on pp. 525 to 530 inclusive.

THE DISCUSSION

MR. ALDEN:—What success has been had in the manufacture of screws, bolts and nuts adhering to these tables?

G. S. CASE:—Very little work in this direction has been done because the tables as a whole have been adopted as standard only by the Army and the Navy. They have never been published in a form permitting the average manufacturer to use them. The intention is to present them so that manufacturers can use them. It is probable however that after they have been used somewhat, some changes will have to be made in them, but we do not know of any way to try them out except by putting them out. As a result of study, it is believed that they are in good condition to use at the present time.

The work of the Screw-Threads Division is different from that of other Divisions in that the automobile industry does not use much over 5 per cent of the bolts, nuts, screws and similar articles that are made. What we want to do is to arrive as nearly as possible at a standardization that can be used by all the industries. The great trouble has been that each industry has been standardizing from its own point of view. It has been the purpose of the National Screw Thread Commission, the Sectional Committee and the Screw-Threads Division to bring about uniform screw-thread standardization.

(27) SCREWS, BOLTS AND NUTS

The Screw Threads Division recommends that the explanatory text in the S.A.E. Standard for Screws, Bolts and Nuts, p. C2 of the S.A.E. HANDBOOK, be revised and extended to read as recommended on p. 530.

SPRINGS DIVISION REPORT

(28) FRAME BRACKETS FOR SPRINGS

The Springs Division recommends that the present S.A.E. Recommended Practice for Frame Brackets for Springs, p. H6 of the S.A.E. HANDBOOK, be cancelled.

(29) SPRING-EYE BUSHINGS

The Springs Division recommends that the present S.A.E. Recommended Practice for Spring-Eye Bushing and Bolt Tolerances be revised by the elimination of the bolt tolerances, the title of the Recommended Practice to be changed to "Spring-Eye Bushings."

STATIONARY-ENGINE DIVISION REPORT

(30) FLYWHEEL PULLEY LUGS

The Division recommends that the flywheel pulley lug dimensions given in the table on p. 484 be adopted as S.A.E. Recommended Practice.

UNACCEPTED RECOMMENDATIONS

ENGINE DIVISION

CRANKCASE DRAIN-PLUGS

The Engine Division recommends for S.A.E. Recommended Practice that crankcase drain-plugs shall have a minimum opening of ¾ in., be located at the lowest point of the oil-pan and be operable from under the engine hood.

[This subject, which was printed on p. 478, was referred back to the Division with the suggestion that it be discontinued inasmuch as it involves primarily a matter of design.]

THE DISCUSSION

MR. CRANE:—I do not want to be misunderstood in raising a question about this proposed recommended practice, but I think that the members ought to realize that in adopting this report we would be starting an entirely new kind of standardization, not of dimensions for the purpose of interchangeability, but a compendium of proper engineering practice.

No doubt this recommendation is excellent engineering practice. It might be that the Society would like to go much farther and eventually produce a standards book that would contain a lot of excellent advice for the designer, but I think we want to realize now what we are starting to do and decide whether we want to go through with it to the end.

MR. CHASE:—Is it proposed to use a ¾-in. or a ½-in. pipe plug? If not, how is this opening to be closed?

MR. CRANE:—I think that what Mr. Chase has said emphasizes the point that we are not attempting to standardize a dimension here. This recommendation is simply that any hole smaller than one of ¾-in. diameter is too small to drain the case in the shortest time, and that it ought to be as big as that or, as I have found, preferably it should be much bigger. The Division is not in a position to standardize the fittings or any other feature of this at the present time and the question is whether in view of that we should do anything about it at all. I only want to bring out the underlying principle of this kind of standardization.

CHAIRMAN JOHNSTON:—I think most engineers would agree with you on that subject.

A. L. CLAYDEN:—I agree entirely with Mr. Crane. At the same time, some of us might like to have a recommended standard size for oil-plugs, where these are used, specifying a diameter of ¾ in. and, if you like, a particular thread. If anybody improves on that, in the way of a device, well and good, but I think there might be a certain amount of value in having a standard oil-plug that at least would not be smaller than ¾ in.

R. J. BROEGE:—The Division found that the present oil-plugs are too small, and wanted to formulate a recommendation that would help to improve this part of the engines.

T. Y. OLSEN:—I think that the Division in studying this subject considered it more from the user's viewpoint. Possibly the members who use cars have had some difficulty in draining the oil out of the crankcase. We should provide some means for bettering this situation.

CHAIRMAN JOHNSTON:—I think we all will agree that anything that will induce designers to make these drain-holes large enough and put them in a convenient place would be desirable.

MR. ANDREW:—There was a matter somewhat similar to this before the Electrical Equipment Division last year in connection with wires and cables. We felt that considerable could be done to indicate to manufacturers how large a cable should be used, but we did not think it was a fit subject for standardization. So we arranged for one of our members to present a paper on the subject. This largely accomplished the purpose.

PRESIDENT BACHMAN:—I am inclined to feel that Mr. Crane has raised a point that is worthy of our serious consideration, not by any means depreciating the work of the Division. The Division has tried to make a good recommendation, but the subject relates, I think, to invention and not standardization. Many of us would like to find a way of getting a hole big enough to drain the crankcase properly and have a device to this end operable from above the car, so that we would not have to put on a pair of gloves or a suit of overalls to do the job.

W. G. WALL:—I think Mr. Bachman has hit the idea exactly. Peculiar as it may sound, the crankcase drain-plug is in the embryonic stage for the present. For a good many years we have used an ordinary plug. It is

not the function of the Standards Committee to do the designing for the entire automobile industry, but no doubt the industry will be very glad to improve the designs.

Therefore, I think that this matter should be left in abeyance and not even the size of the opening specified at present, as that would handicap some of the work that I know different engineers are doing, from which they will probably get some results during the next year.

Motorcycle Carbureter Flanges

[This subject was withdrawn as a report to be approved at the Standards Committee meeting because of criticisms that had been received, and was referred back to the Division for further study.]

NON-FERROUS METALS DIVISION REPORT

Specification No. 83, Soft or Annealed Copper Wire

[This specification, which was printed on p. 483, was referred back to the Non-Ferrous Metals Division for joint consideration with the Electrical Equipment Division inasmuch as the latter is now working on the preparation of specifications for magnet wire and it was considered desirable to have but one specification for this class of material.]

THE DISCUSSION

Mr. Andrew:—Is this specification intended to include magnet-wire?

Mr. Pack:—As stated in the General Information, it is intended mainly for electrical purposes.

Mr. Andrew:—The Society has a Sub-Division that is working on magnet-wire, in connection with the American Society for Testing Materials and also the American Engineering Standards Committee, and we hope to get a magnet-wire specification that will be unusually good. I feel that this specification goes only half-way and that it should be referred to the Electrical Equipment Division for joint consideration with the Non-Ferrous Metals Division later on.

Mr. Burnett:—Is this specification intended to cover annealed wire for both mechanical and electrical purposes, or will it be necessary to have separate specifications?

Mr. Pack:—The object was to cover both, but we eliminated some of the physical properties given in the American Society for Testing Materials handbook because we thought them burdensome. The main object of the specification was for all mechanical purposes in automotive practice, but I think one set of specifications covering both electrical and mechanical uses would be more desirable.

Mr. Manly:—I move that this matter be referred to the Council with the request that it be investigated as to whether it should be referred only to the Electrical Equipment Division or jointly to the two Divisions, to determine upon a suitable specification.

[The motion was seconded by Ernest Wooler, and carried.]

SCREW THREADS DIVISION

Gages and Gaging

The Screw Threads Division recommends that the statement submitted by Mr. Buckingham and printed on pp. 530-532 be approved by the Standards Committee for publication as general information only.

[This subject was referred back to the Division for the purpose of including more extensive consideration of gaging for lead error in screw-threads.]

THE DISCUSSION

Mr. Crane:—This report on Gages and Gaging is very creditable but it does not deal sufficiently with the importance of gaging for lead error. Manufacturers of nuts, bolts and screws have not talked much about these errors because they have great difficulty in controlling them. Yet the matter is very important. I would like to see this report modified by putting more emphasis on the question of gaging for correctness of lead.

SPRINGS DIVISION

Definitions

[This subject, which was printed on p. 532, was referred back to the Springs Division for further consideration in line with the discussion at the Standards Committee meeting.]

THE DISCUSSION

Mr. Crane:—In this report the definition of Free Height does not appeal very much to me, as a definition. It is given as

> the distance from a line through the center of the spring-eyes to the face of the axle-pad, when the spring is in a free, unloaded position.

About half of the springs used are underslung, the others being overhung. Under this definition the same spring could have two free heights.

The definition for Load Height as

> the distance from a line through the center of the spring-eyes to the face of the axle-pad, when the spring is deflected to rated load

is likewise ambiguous, referring to the axle-pad that may be above or below the spring.

W. C. Keys:—A line drawn through the center of the spring-eyes will not in many cases be parallel to the face of the spring-seat, and the distance of free height should be measured perpendicularly to the line through the eyes to the center of the spring-seat, preferably at the outside of the spring. This definition, as Mr. Crane states, leaves it optional to measure to either the inside or the outside of the spring, depending on whether it is overslung or underslung.

In connection with the definitions of Free Height and Load Height the internal or interleaf friction in the spring is not taken into account. I have laid leaf-springs on the floor on their side and tapped them to take out all inherent tendency to flex one way or the other, and get one height. Then they were put on a spring testing-machine, compressed and the load taken off slowly. Upon again measuring the free height there would be perhaps $\frac{3}{8}$-in. difference from the first measurement. I think this point should be considered in the definition.

Walter W. Wells:—The definition of flexibility disagrees with my ideas of what it should be. According to this definition, a spring that requires 600 lb. to deflect it 1 in. would be expressed as having a flexibility of 600 lb. I would expect the number to indicate its stiffness rather than its flexibility.

PROGRESS REPORTS

In addition to the various recommendations that were discussed and voted on at the meeting of the Standards Committee, three progress reports were presented. These reports with such discussion as followed their submission are printed below.

The progress report of the Parts and Fittings Division on Brake Linings was not presented on account of lack of time. The progress that is being made on this subject will be published in future issues of The Journal.

BALL AND ROLLER BEARINGS DIVISION

Metric Thrust Ball-Bearings

This report is submitted as one of progress on the

standardization of the Metric Series of Ball Thrust-Bearings. The Subdivision has been working toward the complete standardization of light, medium and heavy series in each of the following types:

Single-Direction Thrust—Flat Type
Single-Direction Thrust—Self-Aligning Type
Double-Direction Thrust—Plain Type
Double-Direction Thrust—Self-Aligning Type

making a total of 12 series of metric sizes.

In beginning this work difficulty was encountered in that dimensions of thickness and outside diameter of the bearings, as established by the several manufacturers, were not the same for corresponding bore diameters. These discrepancies have been reconciled by adding to or taking from dimensions of the individual manufacturers. For the most part, dimensions have been increased to meet the existing individual standards, thus working toward the strengthening of thrust-washer sections and eliminating the weaker parts in the several series.

In the self-aligning series there was considerable variation in the dimension of the corner radii, and in the thickness of the self-aligning seat. These differences have been eliminated and, in addition, specific dimensions giving the location for the center of the corner radii have been specified. This is important, particularly to the users of self-aligning ball-bearings, as frequently they desire to incorporate the self-aligning seat as an integral part of their mechanisms. In the past they have been at a loss to determine this center-point accurately.

In the proposed standards the present established dimensions of both foreign and American ball-bearing manufacturers have been included as a basis for undertaking this work, but in order to obtain consistent series in the double-direction type it has been found necessary to develop a new light-series in both the plain and the self-aligning constructions. These will correspond with the light-series single-direction type.

The proposed bearings as developed so far have the general approval of the Subdivision and it is hoped to complete the work and submit the recommendation to the Ball and Roller Bearings Division at an early date for its approval.

ENGINE AND PASSENGER CAR DIVISIONS

Engine and Frame Numbers

At the meeting of the Society's Special Committee on Automobile Insurance, the Insurance Committee of the National Automobile Chamber of Commerce and representatives of the Underwriters' Laboratories in September 1920, the problem of devising methods of numbering automobile engines and frames was discussed in connection with a schedule of automobile insurance hazards that was under consideration at that time. Several methods were suggested which were circularized among automobile and engine manufacturers.

It soon became evident that the problem would require special treatment and it was therefore assigned jointly to the Engine and Passenger Car Divisions, which have discussed it at their meetings and made samples of a number of methods that will be submitted to the Underwriters Laboratories for test to determine their effectiveness. The work has been given considerable publicity throughout the country for the purpose of obtaining ideas from as many sources as possible.

The underwriters have stipulated that whatever methods are recommended must be approved not later than Jan. 1, 1923, to have the reduced theft-insurance premiums effective.

THE DISCUSSION

R. S. Begg:—Perpetual motion has nothing on the subject of non-changeable numbers for frames and engines. The problem is to obtain a system of numbering such that the numbers cannot be changed or obliterated without any layman or policeman being able to detect this. For instance, if the numbers were on detachable plates and when a new plate was put on bearing a different number, the change could be detected easily; it would be considered that we had a successful system.

The location of the numbers is not of direct interest at the present time as we are interested primarily in getting some system that will be satisfactory to the Society and pass the Underwriters Laboratories test. If we can get such a system it will not be hard to find a suitable location for the numbers on the frames and the engines.

The object in studying this matter is to lessen the ease with which the means for identifying stolen cars can be obliterated, and to secure lower premiums on car theft-insurance. The possible amounts to be saved in theft insurance has not been investigated thoroughly. It is very difficult to determine any specific saving because theft-insurance premiums vary, depending on both the make of car and the locality. It will be feasible of course to get only a general average that will be a reasonable estimate. We have been informed, however, that for cars having either an engine or frame approved numbering method, there will be allowed a 7½-per cent reduction in premium, whereas the total reduction will be 20-per cent if both are numbered according to methods approved by the Underwriters Laboratories.

We have received many letters suggesting all kinds of schemes and offering patented devices. Among the suggestions received are

(1) Casting numbers on the crankcase. Such a method would not, of course, apply to frames
(2) Concentric expanded discs
(3) A special alloy cast in the crankcase
(4) A checker-board system
(5) A small thin fin cast on the crankcase on which numbers could be stamped. The numbered fin would be broken off by the dealer and held for the purchaser
(6) Raised number-plates welded to the frame
(7) Armor-plate number-plates riveted on, using two or more rivets which enter into the frame construction
(8) Fairly large numbers embossed deeply into the frame
(9) Small holes punched or drilled into the frames at places where the frames would not be weakened
(10) Numbers inset under a glass cover in a spring-bracket or other accessible casting or forging in the frame assembly. This system is applicable to engines also
(11) A thin plate, with the number embossed on it, held in a frame or riveted or blind-screwed to the car frame
(12) A thumb-print system
(13) An armored plate riveted into position, with special seals placed over the rivets. [See page 211 for an illustration of this method]
(14) Case-hardened plugs or plates bearing the numbers fastened into the frame with blind screws or some other such device. This method is applicable also to engines
(15) A plate of bakelite or similar material over the numbers, fastened behind the frame channel as in the preceding suggestion. This is applicable to engines also

(16) A series of embossed nickel plates set in the frame or engine in such a way that they could not be removed without tearing down the engine or frame. The reason for advocating nickel is that it is not easily affected by the acetylene torch. [See this page for an illustration of this method]

Several suggestions have been embodied in samples submitted for inspection today. These will be sent to the Underwriters' Laboratories for their experimentation. Among the samples are

(1) A front spring-hanger having a forged depression into which is set a series of thin nickel-plates with perforated numbers. The plates are held in position by the spring-hanger rivets, the numbers showing through a slot cut in the channel of the side-rail. If necessary, these can be welded-in. [See this page for an illustration of this method]

(2) A heat-treated nickel-steel plug with numbers stamped on circular serrations, held in the side-rail by a heat-treated nut, with a set-screw locking it and the head broken off. [See this page for an illustration of this method]

(3) Same as No. 2, except that it is made of tool-steel

(4) Numbers in a bakelite cap molded on a heat-treated nickel-steel plug held in the side-rail by a heat-treated nut locked on by a set-screw with the head broken off. [See this page for an illustration of this method]

(5) Circular serrations cut in the side-rail by the frame manufacturer; on which the car builder would stamp the serial number. [See this page for an illustration of this method]

(6) Sine-waves pressed into the side-rail by the frame manufacturer; on which the car builder would stamp the serial number. [See this page for an illustration of this method]

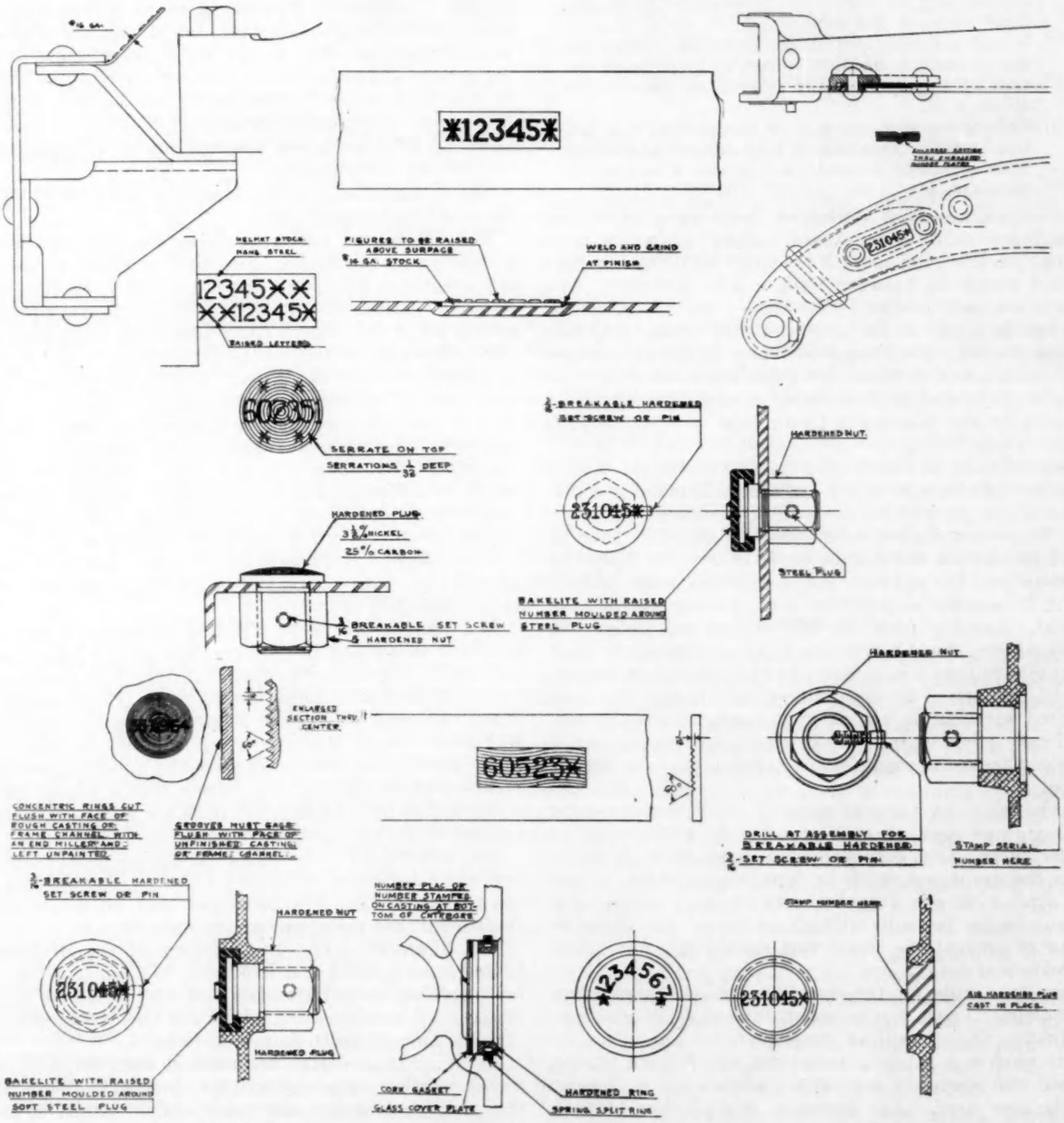
12345
HELMET STOCK
MANG. STEEL
12345XX
XX12345X
RAISED LETTERS
FIGURES TO BE RAISED ABOVE SURFACE
WELD AND GRIND AT FINISH
SERRATE ON TOP
SERRATIONS 1/32 DEEP
HARDENED PLUG
3 1/2% NICKEL
25% CARBON
1/4 BREAKABLE SET SCREW
5/8 HARDENED NUT
1/4-BREAKABLE HARDENED SET SCREW OR PIN
HARDENED NUT
STEEL PLUG
BAKELITE WITH RAISED NUMBER MOULDED AROUND STEEL PLUG
ENLARGED SECTION THRU CENTER
60523X
CONCENTRIC RINGS CUT FLUSH WITH FACE OF ROUGH CASTING OR FRAME CHANNEL WITH AN END MILL, & AND LEFT UNPAINTED
GROOVES MUST GAGE FLUSH WITH FACE OF UNFINISHED CASTING OR FRAME CHANNEL
HARDENED NUT
DRILL AT ASSEMBLY FOR 1/4-BREAKABLE HARDENED SET SCREW OR PIN
STAMP SERIAL NUMBER HERE
1/4-BREAKABLE HARDENED SET SCREW OR PIN
231045X
HARDENED NUT
HARDENED PLUG
BAKELITE WITH RAISED NUMBER MOULDED AROUND SOFT STEEL PLUG
NUMBER PLAC OF NUMBER STAMPED ON CASTING AT BOTTOM OF CNTERBORE
CORK GASKET
GLASS COVER PLATE
HARDENED RING
SPRING SPLIT RING
123456
231045X
STAMP NUMBER HERE
AIR HARDENED PLUG CAST IN PLACE

FIG. 2—SOME OF THE METHODS PROPOSED FOR NUMBERING ENGINES AND FRAMES

(7) A tool-steel plug held in the wall of the crankcase by a heat-treated nut locked with a set-screw with the head broken off. [See page 211 for an illustration of this method]

(8) The same as No. 7 except that it is made of nickel-steel heat-treated

(9) Numbers in a bakelite cap molded onto a heat-treated plug held in the crankcase by a heat-treated nut, locked on by a set-screw with the head broken off. [See page 211 for an illustration of this method]

(10) Numbers stamped on the crankcase wall and a glass placed over the numbers. The glass rests on a cork gasket and is held in place by a snap-ring of liberal size that locks in a groove cut in the case, a steel ring pressed flush into place concealing the snap-ring. [See page 211 for an illustration of this method]

(11) A heat-treated tool-steel plug cast in the crankcase. A chill is put across the plug so the heat in casting will not soften it. [See page 211 for an illustration of this method]

(12) Nickel numbers cast in an aluminum crankcase, the numbers being high enough to go through the wall of the casting and project on the outside about ⅛ in.

(13) This is the same as No. 12 except that it is an iron casting. It would be very difficult to destroy these numbers without cutting out a section of the crankcase

J. B. FISHER:—Last winter we made up some sample plates representing a crankcase casting, on which were cast two parallel ribs about 3 in. apart with the numbers stamped deeply in between with a 5-lb. hammer. The plates were sent to the Underwriters Laboratories for test, but in about 2 hr. they returned them, with the original numbers obliterated and new numbers stamped in. A description of these plates and the method of numbering was printed in THE JOURNAL last December and discussed at the Standards Committee meeting in January.

I believe that we cannot get up a system that cannot be beaten, but we can devise one that will make it a difficult and lengthy process for a thief to change the numbers. One such system, which may be about as good as any, is to stamp a number in 10, 20 or even 30 places on the frame and the engine. While this may seem foolish, I think it is about as practical a suggestion as we have received. Another point in this connection, which was mentioned by the Underwriters Laboratories, is that automobile thieves will seldom if ever attempt to change all such numbers. If one number which has not been tampered with can be located upon inspection of the suspected car, it is a simple matter to get a complete record of the car from the manufacturer, and a positive identification.

I prepared a few samples some of which we succeeded in changing so easily that it was hardly worth while to consider them. One consisted of a small piece of brass cast in the crankcase, with an impressed number somewhat similar to the raised safety-marking on checks. This numbering is really difficult to change but there is nothing to prevent the thief from soldering a new piece on quickly and easily.

There is a side to the question that has not been brought out. There are so many thousands of automobiles in use that it will be possible for a long time to come to remove a safety number entirely from a car so equipped and stamp in any other number in the simple methods now used. For instance, one of the methods used with a hardened-steel plug could be changed by knocking the plug off entirely, covering up the spot with a plate and stamping any other number somewhere else on the frame or the crankcase. A man suspected as the thief can claim that that is his number and a check on it would necessitate considerable time and effort. This is one of the phases of the subject we hope to overcome.

We should try to get the insurance underwriters to modify their requirements to the extent that they will approve a numbering system that is difficult to change and not require one that it is "impossible to change." We have experimented enough to know that almost anything can be altered, and if they will meet us half-way and accept a method or methods that will make it difficult to change the number, even though it can be changed easily in the laboratory, I think we will have accomplished something worth-while.

A. D. T. LIBBY:—Which one of the devices shown do the Divisions think the most of?

MR. FISHER:—That is an embarrassing question. It is largely a matter of relative value, as a few minutes of study will bring out the weakness of any one of the suggested methods. We do not know yet whether the Underwriters Laboratories can succeed in all these systems. It has been pretty successful so far in this respect in the case of the samples we have submitted.

W. C. KEYS:—Cannot the solution of this problem be left to the Underwriters?

MR. FISHER:—I do not know. I have not talked to them in that connection.

R. S. BURNETT:—This problem was first discussed at a meeting of the Society Special Committee on Automobile Insurance Schedules, the Insurance Committee of the National Automobile Chamber of Commerce and representatives of the Underwriters Laboratories in September 1920. We are relying on the Underwriters Laboratories to prove out what we devise. The Underwriters Conference became interested and intimated that if a numbering system for either engines or frames that would be proof against changing were devised, the reduction in theft-insurance premiums that has been specified here today would be allowed. The Underwriters Conference will not act in this connection upon anything that has not had the approval of the Underwriters Laboratories.

C. M. MANLY:—I would like to ask if the underwriters agreed that they would not raise the rates just before they make that reduction?

MR. KEYS:—All these different samples we have seen are very clever and interesting, but who is going to pay the bill? The manufacturer certainly will object, especially if he has a large production. If a small additional cost will be applied against the manufacturer, it will simply mean that the thing will not be adopted by him. But, as has been suggested, the underwriters might recommend something the owner would gladly comply with, and at his own expense have the numbering system applied to his car, and thus reduce his insurance.

MR. LIBBY:—If a car has an approved numbering system, the salesmen will use as a talking-point the fact that the buyer will get 7½ or 20-per cent reduction of his theft-insurance premium, as the case may be.

MR. BURNETT:—The first problem of the Divisions is to find some method that looks possible and feasible. The next problem is to reduce its cost to the lowest possible amount. We may not be able to get that combination but it is the aim of the Divisions to do so.

W. W. WELLS:—Has the method been tried of using secret numbers throughout the chassis, covered up so they could not be seen and their location would be known to only the manufacturer?

ENGINE CRANKCASE OILS

Tentative specifications, June 20, 1922

General.—These specifications cover grades of petroleum oil for the lubrication of internal-combustion engines, except aircraft, and are not recommended for the lubrication of turbines.

Only refined petroleum oils without admixture of fatty oils, resins, soaps or other compounds not derived from crude petroleum will be considered.

Specification No.*	Flash-Point, Min.	Fire-Point, Min.	VISCOSITY, SAYBOLT SEC.				Color (NPA) Darkest color allowed on mixture of oil and 50 per cent kerosene	Pour Test, Max.	Acidity, Mg. KOH per Gram, Max.	Conradson Carbon Residue, Per Cent, Max.	Corrosion Test
			100 Deg. Fahr.		210 Deg. Fahr.						
			Min.	Max.	Min.	Max.					
20	325	365	180	220	42	....	5	35	0.15	0.20	Required for all grades
020	325	365	180	220	42	....	5	0	0.15	0.20	
30	335	380	270	330	44	....	5	40	0.15	0.30	
030	335	380	270	330	44	....	5	0	0.15	0.30	
40	345	390	360	440	46	....	5	45	0.15	0.40	
50	355	400	450	575	50	....	6	50	0.15	0.60	
60	360	.....	.....	.....	55	65	.....	55	0.15	0.80	
80	380	.....	.....	.....	75	85	.....	55	0.15	1.50	
95	390	.....	.....	.....	90	100	.....	55	0.15	1.75	
115	400	.....	.....	.....	110	120	.....	60	0.15	2.00	

*For Specifications Nos. 20 to 50 inclusive, the numbers indicate the first two figures of the average Saybolt viscosity in seconds at 100 deg. fahr. of the grades indicated. The first cipher in Specifications Nos. 020 and 030 indicates that the pour-test value of these two grades is zero. Nos. 60 to 115 inclusive indicate the average Saybolt viscosity in seconds for these four grades at 210 deg. fahr.

Corrosion Test.—The following corrosion test shall not cause discoloration of copper strip. Place a clean piece of mechanically polished pure strip copper about ½ in. wide and 3 in. long, and 10 cc. of the oil to be tested, in a clean test-tube. Close the tube with a vented stopper and hold for 3 hr. at 212 deg. fahr. Rinse the copper strip with sulphur-free acetone and compare it with a similar strip of freshly polished copper.

MR. BEGG:—I think there is no doubt that the people who steal cars would soon find such numbers. The suggestion was made that we have a thief on the Divisions to test out these devices. The people who are stealing cars are pretty well organized and are prepared to steal almost any car they want.

MR. BURNETT:—One of the main objects of such a numbering system is to have the number in plain view where a constable or policeman can see it. Covering the numbers up would, I think, probably defeat the whole project because no policeman or constable would be permitted to tear a man's car partly apart to inspect the numbers.

CHAIRMAN JOHNSTON:—To devise a system that will be satisfactory to the insurance companies and the car builders is a difficult task. On the other hand, if the insurance rates can be reduced 20 per cent, the attempt is certainly worth while from the economic standpoint.

MR. BEGG:—If anybody has further suggestions to offer, he should submit them in writing to the Society offices in New York City. We will make up samples for testing. The assistance of all the members is solicited. It will be necessary to have such suggestions promptly, however, because Jan. 1, 1923, is the time limit that has been set by the Underwriters Conference on the development, testing, approval and adoption of such a method of numbering engines and frames of automobiles.

LUBRICANTS DIVISION

CRANKCASE LUBRICATING OIL

One of the most important subjects before the Standards Committee is the establishing of definite specifications for different grades of engine crankcase oil used by the several groups of the automotive industry. The Lubricants Division was reorganized on an active basis in 1921 and work started on formulating practical specifications for crankcase oils, cup greases, transmission greases and other classes of lubricant. The work of the Federal Government, conducted by the Bureau of Mines in the Interdepartmental Committee on the Standardization of Petroleum Specifications, and the standard methods of testing adopted by the American Society for Testing Materials, have been considered carefully by the Division.

The accompanying table is the last revised specification proposed by the Division as the result of the discussion at White Sulphur Springs. The first specification was circularized, together with a questionnaire, by the Society in November 1921 and revised at a meeting of the Division in April 1922, as printed on p. 533 of the June issue of THE JOURNAL.

THE DISCUSSION

H. C. MOUGEY:—A meeting of members of the Lubricants Division, including H. C. Mougey, chairman, Sydney Bevin, P. J. Dasey, Dr. W. H. Herschel, K. G. Mackenzie, J. W. Stack and a number of guests representing producers and users, was held this morning (June 20). As a result of the viewpoints expressed by different engineers, some changes were made in the table of proposed specifications that was printed in the June issue of THE JOURNAL on p. 533. In Specifications Nos. 20 and 020 the minimum viscosity, Saybolt, at 210 deg. fahr., was changed to 42 instead of 43; in specifications Nos. 30 and 030, to 44 instead of 46; in No. 40, to 46 instead of 49; and in No. 50, to 50 instead of 52. The limit on the viscosity for No. 50 at 100 deg. was extended to read from 450 to 575 instead of from 450 to 550.

In Specification No. 80 the minimum flash-point was lowered to 380 and the maximum pour-test raised to 55. In Specification No. 95 the minimum flash-point was lowered to 390, the maximum pour-test raised to 55. The Conradson carbon-residue was raised to 1.75.

A new Specification, No. 115, was added, having a minimum flash-point of 400, nothing being specified under fire-point or viscosity at 100 deg. fahr.; the viscosity

at 210 deg. is 110 minimum and 120 maximum. Nothing is specified for color. The pour test is 60; acidity, 0.15; Conradson carbon-residue, 2.00.

The precipitation numbers for the entire series of oils were eliminated.

A column for corrosion tests, required on the entire series of oils, was added. The corrosion-test temperature, previously specified as 210 deg., was changed to 212 deg. fahr., to correspond with the corrosion test specified by the Interdepartmental Committee on the Standardization of Petroleum Products.

The revised specifications are presented in a tentative form and the Division is anxious to have as much help as possible from the members in making these specifications of the greatest possible use to the industry.

One question that has been raised is the drafting of these specifications so that they will conform with those prepared by the Interdepartmental Committee and with other specifications that are largely used, and a meeting is being planned to be held in July at which the Society, the Interdepartmental Committee and the American Petroleum Institute will make such progress as can be made along those lines.

Another question is that of designating names for the several grades of oil, such as "light," "medium" and "heavy," instead of the proposed series of numbers. Unfortunately, nobody has found enough names to go around. Suggestions in this connection will be appreciated by the Division.

CHAIRMAN JOHNSTON:—Is there any discussion of this progress report of the Lubricants Division?

P. J. DASEY:—If these recommendations are adopted as we have them now, how will we get the oil commercially on the market to conform to the specification numbers? I am not looking at the matter from the engineering point of view so much as from the standpoint of the everyday user of the product.

MR. MOUGEY:—That is the particular problem that is before us. We hope to have suggestions that will make for progress in this connection at the joint meeting of the Society, the Interdepartmental Committee and the American Petroleum Institute.

MR. DASEY:—We have 10 different numbers in the series. That would mean practically two light, two medium, two heavy, two extra heavy and two extra extra heavy grades, to include them all. I doubt whether many oil companies can meet these specifications.

MR. MOUGEY:—These specifications were drawn up in such a way that they can be met very generally.

C. W. STRATFORD:—In the discussion of these specifications this morning the only point to which I objected is that the acidity value of 0.15, given in the tabulation, cannot be met by any California oil at the present time. It would be rather a costly operation and would mean a fundamental change in processing methods to do it.

I represent the Associated Oil Co. of California and am familiar with what the other producers are able to do. We have produced oils with zero acidity. These oils give better results in engines than those of higher acidity. It seems that such specifications as these will ultimately force the oil companies to refine their oil so as to produce the zero acidity.

There is generally relatively little difference in the durability of the oils, as usually they are drained out after 500-miles' running. The difference is very marked in the operation of tractors, as at the end of 2 hr. a breakdown in the oils of high acidity is worse than in the case of oils of low acidity.

To produce the highest grade of heat-resisting oils from California crude, we manufacture a very heavy oil and blend it in certain proportions with the Eastern light-stock. The effect of adding Eastern light-stock seems to be protective. There is a sort of flaky carbon-deposit with this blend and yet the heat-resisting properties in regard to the crude from which it is made seem to be fully equal to that of the highest grade of paraffin-base or any other crude oil.

As to the grading, I think this is a serious specification as applied to California oils. The range of grades seems to me to be rather indefinite, each grade varying considerably. But there is a good reason for that variation. Lubricating oils made from different crudes vary widely. The viscosity drops very much more rapidly with an increase of temperature in the case of California oils than of straight-run oil from Pennsylvania. If we do not adopt specifications such as these, the only alternative would be to draft specifications for lubricating oils made from the Pennsylvania and from the Mid-Continent crudes; with perhaps a separate classification for the Gulf-Coast oils, and a distinctively separate classification for California oils.

DR. E. W. DEAN:—With regard to the organic acidity, the present limits seem to cover pretty well the Eastern and Mid-Continent oils. The acids found in the California oils are, according to information, present in sufficiently greater quantities to make a special refining process necessary to bring them within this specification. From that point of view it might be that the acidity test should be dispensed with, because it is doubtful whether the gain in the wearing quality of the oil is sufficient to make up for the additional expense in refining.

An automobile oil is not treated very well after it is put into an engine. For instance, some of the light oils have colors specified, but after one has been run in an engine a very few miles it cannot be determined whether it started at No. 1 or No. 67 color. The only value of color specification is that it is a certain index of the care in refining. In the same manner the organic acidity is an index. Eastern and Mid-Continent oils will give an acidity inside the specified limit, whereas the same degree of care in refining California oils results in an acidity several times greater. I think it doubtful whether it would be a benefit to the consumers to enforce the acidity limits on the Western oils.

With regard to the grades of oil it is rather hard to draft specifications on account of the differences in chemical constitution of oils, but I think the present figures are about as good a compromise as can be had. It is difficult to draft a general specification for lubricating oil that would be suitable for a given automobile to be produced from either an Eastern or a California crude.

W. H. HERSCHEL:—These specifications were reviewed rather thoroughly this morning and the changes that were decided upon make them less stringent. There should not be any objection to them from the oil-refiner's point of view.

Although there is a specification as to color test, I think that every oil-refiner will agree that there is not an oil on the market, or a probability that there will ever be, that will be ruled out on account of this, because the color is determined after dilution with 50 per cent of kerosene.

I think that sufficient emphasis has not been put upon the fact that the acidity test is probably the only one among all those specified that gives any indication of the probable durability of the oil. Emphasis should not be put on carelessness in refining. It is not a matter of concern to users of oil how much care is necessary to get oil

refined. The question is whether the product as finally offered for sale is of a serviceable nature. I do not think that the high acidity in California oils indicates that the California refiners are a bit more careless in refining their oils than the Eastern refiners are. It does indicate that the California crude is less stable chemically, and therefore will deteriorate in the refining and in the use. This question of acidity is one of great importance to the users of oils.

MR. STRATFORD:—What does acidity mean in terms of service? What do the emulsifying properties have to do with service, since after running non-emulsifying oil for 5 min. in an engine, there is a considerable emulsion of water? I would also like to ask Dr. Herschel whether the California oil treated with 0.1 per cent of soda, before it is treated with the acid, will have zero acidity, and whether the soda removes all of the unstable compounds?

DR. HERSCHEL:—To answer the question categorically, I should say, no. Mr. Stratford said this morning that this extra treatment was necessary to get the low acidity, and would cost only about 2 cents per gal. Therefore, this is not a very severe requirement on a refiner, or on the public which must bear the cost. Mr. Stratford said that the oil of lower acidity is more durable in tractor service; also, I believe that by mixing California oil with Pennsylvania light-stock a more durable oil could be produced. With regard to automobile-engine crankcases being drained at the end of 500-mile runs, this theoretical figure can be found in instruction books issued by automobile builders, but I question very seriously whether the majority of users of automobiles drain the crankcase at the end of every 500 miles. Therefore, I believe that durability of oil is as essential for an automobile as for a tractor.

MR. MANLY:—This discussion brings up the question of whether the test for acidity is made at the proper time. Mr. Stratford asks whether the addition of soda, bringing the oil within the specifications, suffices. It does so far as the test is concerned, but the important thing is whether it has made the oil any better for its intended use.

MR. STRATFORD:—This whole matter of acidity has come to us from the Navy specifications, the reason for its use in them being the limited tankage on-board ship, requiring the Navy to have practically the same class of oil for all purposes, that is, non-emulsifying oils. That does not apply at all to the lubrication of internal-combustion engines.

The divergence between California-oil acidity and paraffin-base oil acidity is approximately in the ratio of 1.5 to 0.1 in the case of a light oil. After several years' experience in engine-oil testing under service conditions, I believe that the only real test for an engine oil is actual use under service conditions. Driving at the usual touring speeds only about 10 or 20 per cent of the attainable horsepower of the average automobile is used. The temperature of all engine parts is low, and it would be foolish to use an oil with a 450-deg. flash-point. The result would be rapid formation of carbon on the piston-heads and in the combustion-chamber at the end of 2 or 3 weeks causing premature ignition and necessitating taking the engine down. If an oil of the correct loading-point range is used, that does not occur; the carbon formed is light and flaky, and is largely blown out with the exhaust.

The paraffin-base oil producers have learned that by burning the paraffin-splinters with Gulf-Coast, California or some Mid-Continent stock, the resultant engine oils come much nearer to meeting the operating conditions of the average automobile than the straight oil of Pennsylvania meets them.

Lubricating tractors is a matter of operating temperatures. If it is desired to operate at high temperatures, as in an airplane engine, an oil of very much higher loading-point must be used, and it becomes almost necessary to use the paraffin-base oil.

ATTENDANCE AT MEETING

The members of the Standards Committee and the Society and the guests in attendance were

Standards Committee Members

Azel Ames
F. W. Andrew
B. B. Bachman
R. S. Begg
S. Bevin
R. J. Broege
A. K. Brumbaugh
T. V. Buckwalter
R. S. Burnett
Clarence Carson
E. R. Carter, Jr.
G. S. Case
C. F. Clarkson
A. L. Clayden
J. Coapman
J. R. Coleman
H. M. Crane
L. A. Cummings
P. J. Dasey
G. W. Dunham
H. E. Figgie
J. B. Fisher
E. S. Fretz
D. E. Gamble
H. B. Garman
G. E. Goddard
W. S. Haggott
W. S. Harley
S. P. Hess
C. E. Heywood
M. C. Horine
F. G. Hughes
H. S. Jandus
E. A. Johnston
L. S. Keiholtz
W. C. Keys
C. H. Kindl
B. M. Leece
A. D. T. Libby
K. G. Mackenzie
C. M. Manly
C. A. Michel
H. C. Mougey
C. T. Myers
W. M. Newkirk
I. M. Noble
G. L. Norris
Leonard Ochtman, Jr.
Charles Oppe
Charles Pack
L. C. Porter
O. J. Rohde
A. J. Scaife
J. W. Stack
L. M. Stellmann
J. G. Vincent
W. G. Wall
E. W. Weaver
R. E. Wells
J. A. White
F. G. Whittington
Ernest Wooler

Society Members and Guests

H. W. Alden
V. G. Apple
C. E. Banta
David Beecroft
George Bell
O. C. Berry
R. E. Blossom
J. T. Caldwell
Herbert Chase
K. H. Condit
H. Copleston
J. T. Crawford
E. W. Dean
W. A. Dick
Ernest Dickey
H. C. Dickinson
J. B. Dillard
A. H. Ehle
F. H. Ford
G. W. Gilmer, Jr.
V. H. Gottschalk
Claude Greenhoe
A. J. Hall
G. A. Hancock
P. M. Heldt
W. H. Herschel
J. W. Hobbs
R. J. Hoffman
Russell Hoopes
G. E. Houser
R. M. Hudson
M. L. Hull
H. W. Jarrow
R. P. Lansing
T. J. Litle, Jr.
W. L. McGrath
Neil MacCoull
H. H. Magdsick
J. F. Marshall
W. H. Miller
F. E. Moskovics
W. C. Munson
A. L. Nelson
Harold Nutt
T. Y. Olsen
Gust Olson, Jr.
O. F. Ostby
B. S. Pfeiffer
N. B. Pope
H. R. Portugal
I. J. Reuter
H. E. Rice
H. J. Saladin
J. S. Schneider
R. H. Sculis
L. R. Smith
M. A. Smith
T. D. Smith
C. W. Stratford
G. E. Strohm
H. W. Sweet
P. S. Tice
E. E. Turner
W. C. Voss
T. A. Waerner
H. L. Walker
E. P. Warner
W. W. Wells
C. E. Wilson
H. F. Wood

Activities of the Sections

Meetings Committee Chairmen

BUFFALO SECTION
W. W. Slaght, Pierce-Arrow Motor Car Co., 1695 Elmwood Avenue, Buffalo

CLEVELAND SECTION
John Younger, 13,515 Lake Shore Boulevard, Bratenahl, Cleveland

DAYTON SECTION
Iskander Hourwich, Antioch College, Yellow Springs, Ohio

DETROIT SECTION
O. E. Hunt, Chevrolet Motor Co., General Motors Building, Detroit

INDIANA SECTION
O. C. Berry, Wheeler-Schebler Carburetor Co., Indianapolis

METROPOLITAN SECTION
C. B. Veal, Manly & Veal, 250 West 54th Street, New York City

MID-WEST SECTION
George W. Cravens, Hotel Lafayette, Clinton, Iowa

MINNEAPOLIS SECTION
L. A. Emerson, 4852 South Washburn Avenue, Minneapolis

NEW ENGLAND SECTION
V. A. Nielsen, V. A. Nielsen Co., 701 Beacon Street, Boston

PENNSYLVANIA SECTION
E. L. Clark, Commercial Truck Co., Hunting Park and Rising Sun Avenues, Philadelphia

WASHINGTON SECTION
William M. Wallace, Bureau of Construction and Repair, Navy Department, City of Washington

FOR the information of prospective authors of automotive engineering papers, there are given above the names and addresses of the members who will select the Section meeting programs during the coming year. If you are considering the preparation of a paper for presentation at a Section meeting, it is important that you write the Meetings Chairman of that Section, making certain that your topic fits in with the general plan he has conceived for the Section year. Submit an outline of your contemplated paper along with the subject. The Chairman is thus enabled to suggest possible extension or revision of the paper.

Photographs of some of the Section Chairmen and Vice-Chairmen are reproduced on the following pages. The following list gives the name of the office and the Section for the various officers.

NAME	OFFICE	SECTION
C. A. Criqui	Vice-Chairman	Buffalo
Victor Gauvreau	Vice-Chairman	Minneapolis
George E. Goddard	Chairman	Detroit
Iskander Hourwich	Vice-Chairman	Dayton
J. H. Hunt	Chairman	Dayton
W. E. Kemp	Chairman	Metropolitan
Taliaferro Milton	Chairman	Mid-West
R. J. Nightingale	Vice-Chairman	Cleveland
O. A. Parker	Chairman	Cleveland
Col. F. H. Pope	Chairman	Washington
H. W. Slauson	Vice-Chairman	Metropolitan
Lon R. Smith	Vice-Chairman	Indiana

Secretaries of the Sections

BUFFALO SECTION
A. J. Fitzgibbons, 168 Claremont Avenue, Buffalo

CLEVELAND SECTION
E. W. Weaver, 5103 Euclid Avenue, Cleveland

DAYTON SECTION
R. B. May, Dayton Engineering Laboratories, Dayton

DETROIT SECTION
Thomas J. Litle, Jr., 733 Seyburn Avenue, Detroit
Mrs. B. Brede, Assistant Secretary, 1361 Book Building, Detroit

INDIANA SECTION
B. F. Kelly, Weidely Motors Co., Indianapolis

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Phil N. Overman, 10 South 10th Street, Minneapolis

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PENNSYLVANIA SECTION
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WASHINGTON SECTION
Benjamin R. Newcomb, 211 Victor Building, City of Washington

W. E. KEMP

GEORGE E. GODDARD

J. H. HUNT

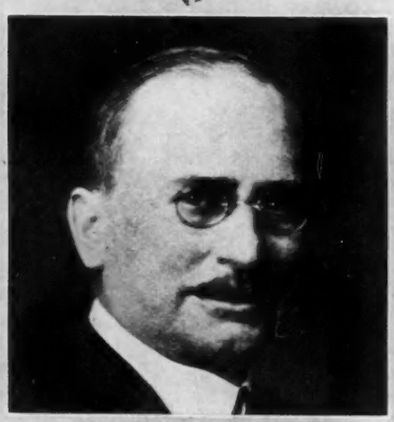
TALIAFERRO MILTON

COL. F. H. POPE

O. A. PARKER

VICTOR GAUVREAU

ISKANDER HOURWICH



C. A. CRIQUI

H. W, SLAUSON

LON R. SMITH

R. J. NIGHTINGALE

AN ECONOMIC FOUNDATION FOR HIGHWAYS[1]

IT has been accepted as a tenet that highway bonds shall be issued for a shorter period than the life of the road. The Cumberland Pike, the first and only great national highway of the early days, was opened to traffic about 1818. Today, after a full century, that highway is still in existence, rehabilitated and carrying an ever-increasing traffic. It is true that, due to changes in overland transportation, there was a long period when this highway fell into disuse and disrepair, but today, with the surfacing repaired and rebuilt, the same road-bed and most of the same waterway structures are serving traffic. The extension of this road from Baltimore to Cumberland, originally a state project, was resurfaced in recent years at a nominal cost. This light surfacing was placed for horse-drawn traffic, but with continued maintenance and necessary reconstruction from time to time, is now carrying heavy automotive traffic. Under the theory just mentioned, for how long a period would the bonds, had the road been so built, have been proper? Apparently the road is in better condition today than it has ever been in the past.

The term "permanent roads" is a fallacy that is responsible for more or less of the unsound theory that has been advanced with reference to bond issues. There are certain of the essentials of road construction, such as the road-bed and drainage structures, that can be built so that the deterioration is so slow that they may be properly termed "permanent." Road surfaces of whatever type deteriorate. Maintenance should begin as soon as the surface is thrown open to traffic, and the higher the cost of the road, the more careful in detail should be the maintenance. Even in a single State conditions vary to the extent that loadings which can be carried without deterioration of some road surfaces will inflict untold damage upon others. Yet under the average regulatory law the utility of the best roadways is not realized in full, nor is the safety of the lesser capacity roadways assured.

Research in the field of the weight of loads that can be carried by different road surfaces is revealing definite information. The influence of subgrade soils, tire equipment, distribution of the loads to the wheels, the speed and many other variables is too complex to be written into law. The seasonal variation alone in the carrying capacity of the road-beds, due to moisture conditions, is one of the most serious of all causes of road damage, and for this single reason the highway authorities must be given wide discretion in traffic regulation.

Our total expenditures for all highway purposes in the United States last year were approximately $600,000,000. An examination of the progress in highway building over the past 10 or 12 years indicates a very serious lag in the development of the road-bed in comparison to the increase in rolling stock. This lag is so serious that there is an insistent demand on the part of the large body of vehicle owners that the providing of improved road-beds shall be hastened. This demand in turn is followed, and properly so, because of the very large expenditures required, by the equally insistent question of who shall pay.

With the exception of a very few States it is apparent that the major highway development for the next decade and probably longer will be upon the so-called 7-per cent system that is now being established under the requirements of the Federal Highway Act of November 1921. We have now on a national scale the inauguration of the first cardinal principle of efficient highway administration, the classification of the roads into selected systems. On the 7-per cent system Federal and State funds will be concentrated until completion. This classification, recognizing with full credit the progress made by many of the States before the federal enactment, is fundamental. Through its operation the roads of greatest importance are first improved and all work done is accumulative toward the completion of a system of interconnected and correlated traffic lines as between the communities within the States and between the States themselves. As the highway systems are completed the traffic will become more and more organized and concentrated on the improved roadways. If these systems are not properly selected they will eventually have to be revised and so much of the investment jeopardized.

It is believed that a proper financial policy will require first that all of the maintenance funds be met from the revenues derived from the road user; second, that the costs of reconstruction be met from the revenues derived from both the road user and from State taxes, the relative percentages being different for different States and for the different types of roadway built; third, after deducting the federal aid, the cost of new construction should be divided between the road users and other State taxes from both urban and road sources.

The total expenditures for rural highway purposes in the United States for the past year came from the following sources:

	Per Cent
Local Road Bonds	33
Federal Aid	14
State Road Bonds	7
State Taxes and Appropriations	12
County, Township and District Taxes and Assessments	14
Motor-Vehicle Revenues	19
Miscellaneous	1

Federal aid and motor-vehicle revenues constituted 33 per cent; the remaining 67 per cent either comes directly or will eventually be paid from State and local taxes. It is believed that a very considerable readjustment of these sources of revenues must be made, so that a larger percentage will be paid by the road user and a lesser percentage from State or local taxes. This statement of motor-vehicle revenues is not fairly representative of the total funds collected directly or indirectly from the motor vehicles, for our estimates show the following revenues paid during the fiscal year 1921:

Federal Taxes Paid by Builders on Passenger Cars and Motor Trucks	$115,546,249
State Registration Fees	122,478,654
Personal Property Taxes	52,500,000
Wheel and Privilege License	3,636,243
Gasoline Tax, 17 States, Calendar Year 1922, Estimated	11,000,000
Total	$305,161,146

The total of $305,161,146 is equivalent approximately to $30 for each car and truck registered during 1921. This total sum, it will be noted, amounts to over one-half of the total estimated road expenditure for 1921.

For over 11,000 miles of federal-aid roads involving a total cost of over $188,000,000, the surfacing cost is 60 per cent and the remaining 40 per cent is made up of: Grading, 22 per cent; structures, 14 per cent; shoulders, 1 per cent; engineering, 3 per cent. That is, 40 per cent of the expenditures were for the permanent features of the road. The greater part of the expenditures for surfacing can be rightfully considered in the same class, for it is being successfully demonstrated that by supplementary construction, such as the placing of new surfaces and widening by addition of shoulders, the greater part of the investment can be continually maintained and thus preserved indefinitely. Expenditures of this class fall into the category of maintenance and reconstruction, and if continuance of these two can be relied upon the original investment is preserved indefinitely. Therefore, little fault can be found with the soundness of the financing if bonds are issued for new construction provided that the original investment is thus continually preserved.

Of all these requirements it appears that the funds for the

[1] From an address delivered at the annual meeting of the Chamber of Commerce of the U. S. A. by Thomas H. MacDonald, chief of the bureau of public roads, Department of Agriculture.

new construction in the amounts that will be needed will be the most difficult to secure. The public should not be called upon to bear this entire cost as an annual expense. Rather is it fair to distribute these costs over a period of years extending beyond the time of the maximum expenditures for new construction. It is not doubtful that succeeding generations will enjoy the use of the highways that are being built now, and there is nothing unfair in pursuing a financial policy that distributes a portion of the cost beyond the immediate period. No enterprise requiring funds in the large amounts that they will be required for the new construction of highways can go forward without anticipation of revenues.

Experience in the administration of highway work has already established certain definite principles without the observance of which it would be highly unsafe to resort to bond issues. The major principles may be outlined as follows:

(1) As a general proposition, State, not local, bonds should be issued for the building of the State highway system. In any case the total amount of bonds to be issued for any one year or over a period of years in any State should be subject to the control of one central body

(2) Sufficient revenues must be derived from the users of the highways to pay all of the maintenance and a percentage of any reconstruction charges

(3) All bond-built highways ought to be maintained under the direct supervision of the State highway department, which also must have jurisdiction of the revenues from the road users. The proper maintenance of all bond-built roads must be considered a first lien upon such revenues

(4) The proceeds of bonds must be devoted to a system of roads so devised that as the system is completed these roads will in fact continually serve the major traffic in the vicinity. This means that the only safe sequence of improvement is in the order that the different sections of the system serve the traffic

(5) Bonds should not be issued in an amount beyond the ability of the traffic of the present and immediate future to pay revenues sufficient for the proper maintenance of the roads built from the proceeds

(6) The types of road built with bonds should be adjusted to the traffic that they will be called upon to bear within the reasonable future

It will be noted that little has been said as to the uses that are to be made of the highways, but it must be remembered that the whole question of highway transportation is in its infant stages. Careful investigations and studies are now going forward to determine both the economic limitations of highway transport and of the necessarily adjusted highway construction. We have made rapid progress during the past 2 years toward such determination, and the suggestions that have been made are based upon an administration of a highway program predicated upon the results and determinations of these scientific researches and investigations.

If permanent policies can be adopted and carried forward without change over a period of years the necessary roads can be built without undue burdens upon the public. The result will depend upon foresight and adherence done by foreseeing now and adhering to safe and sound financial policies.

OBITUARY

EDWARD VASSALO HARTFORD, president of Edward V. Hartford, Inc., New York City, and vice-president of the Great Atlantic & Pacific Tea Co., died June 30, 1922, at his residence in New York City, aged 52 years. He was born May 28, 1870, at Orange, N. J., and following his public school training received his technical education at Stevens Institute, Hoboken, N. J.

From 1897 to 1900 he resided in Paris, France, and when on a visit to the United States in 1898 he brought with him one of the first motorcycles. He was an originator, designer and patentee of shock absorbers in the United States and abroad, being for some time president of the Hartford Suspension Co., Jersey City, N. J., which has manufactured shock absorbers and automobile jacks for a number of years. He is survived by his widow, a daughter and a son.

Mr. Hartford was elected to Member grade in the Society Oct. 30, 1911.

LIONEL N. LOUPRET died from an attack of heart disease on the golf course of the Country Club at Kokomo, Ind., July 1, aged 34 years. He was born at Lowell, Mass., on Nov. 1, 1887, and when only 16 years of age entered the service of the Heinze Electric Co. of that city. This was in April, 1904, a short time before the company began to build ignition apparatus, and Mr. Loupret assisted J. O. Heinze in the production of the first ignition coil made by the company and worked directly under Mr. Heinze's personal supervision. With the exception of a little over a year when Mr. Loupret was in charge of the Detroit branch of the company he spent all of the 16 years he was connected with the organization in the plant at Lowell. He had charge of the inspection, testing and production and from 1915 to 1920 supervised the engineering and experimental department. In March, 1920, he became associated with the Kokomo Electric Co., Kokomo, Ind., in its engineering department and at the time of his death was sales engineer of the firm of the Byrne, Kingston Co., which is also located at Kokomo.

Mr. Loupret was elected to Member Grade in the Society Dec. 4, 1920.

RECENT COUNCIL MEETINGS

AT the Council meeting that was held at White Sudphur Springs, W. Va., on June 19, members in attendance were: President Bachman, Past-President Beecroft, Vice-President Young, and Councilors Crane and Smith.

One hundred and twenty-five applications for individual membership and 30 for student enrollment were approved. The following transfers in grade of membership were made: From Junior to Associate, John Pollitt; Associate to Member, George L. Appleyard, W. H. Hollister, Warwick Ray, James W. Wilford, Linus J. Parker, Charles M. Kearns; Junior to Service Member, E. W. Rounds, J. F. Alcure; Junior to Member, Richard W. Fulton, Edward C. Bartlett.

Various matters connected with the Automotive Production Meeting of the Society to be held in Detroit on Oct. 26 and 27 were discussed.

The following appointments to the Standards Committee were made:

LUBRICANTS DIVISION—K. G. Mackenzie
PASSENGER-CAR BODY DIVISION—S. J. Baum
STORAGE BATTERY DIVISION—J. L. Rupp

The subject of Tail-Lamp Illumination was assigned to the Lighting Division.

A meeting of the Council was held in New York City on July 26.

It is expected that the next meeting of the Council will be held in September.

Applicants *for* Membership

The applications for membership received between June 15 and July 14, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, IVAN L., student, University of Utah, *Salt Lake City, Utah.*

BEAN, WILLIAM LLOYD, mechanical assistant to the president, New York, New Haven & Hartford Railroad, *New Haven, Conn.*

BEAUMONT, JOHN SYDNEY, metallurgist, Ford Motor Car Co. Ltd. of Canada, *Walkerville, Ont., Canada.*

BOSCHAN, ALEXANDER S., student, University of Michigan, *Ann Arbor, Mich.*

BURN, WALTER P., sales promotion and advertising manager, Transcontinental Oil Co., *Pittsburgh.*

BURROWS, LEES J., special service representative, Oakland Motor Car Co., *Pontiac, Mich.*

BUTCHER, HAROLD E., sales manager, Champion Spark Plug Co., *Toledo, Ohio.*

COFFIN, O. W. L., division manager, White Co., *Cleveland.*

COLEY, GLENN, metallurgist, Timken-Detroit Axle Co., *Detroit.*

DAVIDSON, ROBERT P., business manager, *Motor, New York City.*

DAVIDSON, WILBUR S., manager branch office, Rich Tool Co., *Detroit.*

DAVISON, WALTER W., factory manager, Wire Wheel Corporation of America, *Buffalo.*

DESCHAMPS, ROGER P., manager, Standard Automobile Co., *Brussels, Belgium.*

DUBOIS, CHESTER B., mechanical engineer, Jones Speedometer, Inc., *New Rochelle, N. Y.*

ELLIOTT, HARRY C., engineer, Packard Motor Car Co., *Detroit.*

ENFIELD, W. L., manager, lamp development laboratory, National Lamp Works, *Cleveland.*

ERSKINE, ALBERT R., president, Studebaker Corporation of America, *South Bend, Ind.*

GORDON, JOHN RUTHERFORD, body builder, Holdens Motor Body Builders, *Adelaide, Australia.*

GOTTSCHALK, V. H., research engineer, Society of Automotive Engineers, Inc., *New York City.*

GRANT, HUGO B., mechanical engineer, Turbulator Corporation, *Chicago.*

HANCOCK, G. A., engineering and research work, L. H. Gilmer Co., *Tacony, Philadelphia.*

HERMANN, HENRY E., draftsman, Phelps Light & Power Co., *Rock Island, Ill.*

HOLT, HARRY W., secretary, Charles B. Bohn Foundry Co., *Detroit.*

HOOVER, H. EARL, chief engineer, Hoover Suction Sweeper Co., *Chicago.*

JACKSON, H. GARDNER, assistant general manager, Wire Wheel Corporation of America, *Buffalo.*

JAGGER, NORMAN A., salesman, Kelsey Motor Car Co., *Newark, N. J.*

KERBER, JOSEPH H., shop superintendent, Wisconsin Highway Commission, *West Allis, Wis.*

KING, TOWER W., materials testing engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

KNISKERN, WALTER H., chief engineer, Atmospheric Nitrogen Corporation, *Syracuse, N. Y.*

KRAUS, SYDNEY M., bureau of aeronautics, Navy Department, *City of Washington.*

LUTZ, EARL C., assistant superintendent, International Harvester Co., *Chicago.*

MCCARTY, HARRY HARPER, research engineer, General Motors Research Corporation, *Dayton, Ohio.*

MCGOLDRICK, WILLIAM J., vice-president and chief engineer, Power Truck & Tractor Co., *St. Louis.*

MACKENZIE, RUSSELL E., carbureter engineer, Detroit Lubricator Co., *Detroit.*

MACKIE, HORACE S., treasurer and general manager, Electrocar Corporation, *New York City.*

METZ, ALBERT G., editor, Chilton Co. *Philadelphia.*

NEAL, JAMES BENSON, manager, Norton Laboratories, Inc., *Lockport, N. Y.*

NORWOOD, H. E., general manager and engineer, Perfect Window Regulator Co., *New York City.*

OHTSUKA, CAPT. N., Imperial Japanese Artillery, office of Japanese Consul General, 165 Broadway, *New York City.*

PAYNE, F. G., chief mechanical assistant, Shanghai Municipal Electricity Department, *Shanghai, China.*

ROBINSON, FRANCIS T., office manager, Society of Automotive Engineers, Inc., *New York City.*

SALISBURY, C. E., service manager, Hupp Motor Car Corporation, *Detroit.*

SCOVEL, ALFRED J., sales department, Marvel Carbureter Co., *Flint, Mich.*

SEELINGER, W. J., works manager, Ohio Body & Blower Co., *Cleveland.*

SIMPSON, H. W., engineer, Ford Motor Car Co., *Dearborn, Mich.*

STEPHENS, ELTON S., mechanical engineer and inventor, International Harvester Co., *Chicago.*

STOCKINGER, W. L., representative engineering and production departments, Studebaker Corporation of America, *Detroit.*

STREETER, EDWARD L., JR., general manager, J. N. Lapointe Co., *New London, Conn.*

STUTTER, CLINTON L., J. Linek, 6 Washington Street, *Maspeth, N. Y.*

TIMKEN, H. H., president, Timken Roller Bearing Co., *Canton, Ohio.*

WILLS, C. HAROLD, president, C. H. Wills & Co., *Marysville, Mich.*

WITMER, GEORGE, branch manager, Sterling Motor Truck Co., *Brooklyn, N. Y.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between June 10 and July 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

BERKOWITZ, SAMUEL (A) president and engineer, Automotive Products Corporation, *Hazleton, Pa.*, (mail) 325 West Diamond Avenue.

BOCZ, ALEX J. (M) mechanical engineer and designer, 2169 Richton Avenue, *Detroit.*

BROSSEAU, A. J. (A) president, Mack Trucks, Inc., 25 Broadway, *New York City.*

BROWN, GARNET C. (M) research engineering department, United & Globe Rubber Co., Trenton, N. J., (mail) 125 Pleasant Street, *Royal Oak, Mich.*

BROWNING, W. E. (J) civilian instructor, Air Service Mechanics School, Chanute Field, *Rantoul, Ill.*, (mail) P. O. Box 556.

CASON, PAUL B. (J) draftsman, Kimball Motor Truck Co., *Los Angeles, Cal.*, (mail) 1739 South Bronson Avenue.

CLARK, OLIVER H. (M) body engineer, Zeder-Skelton-Breer Engineering Co., 24 Mechanic Street, *Newark, N. J.*

COWAN, WILLIAM ARTHUR (A) assistant chief chemist, research laboratories, National Lead Co., 129 York Street, *Brooklyn, N. Y.*

CREAMER, CHARLES DELL (E S) student, Ohio State University, Columbus, Ohio, (mail) *Washington C. H., Ohio.*

DALE, E. B. (A) assistant professor of automotive mechanics, Colorado State Agricultural College, *Fort Collins, Col.*

FUHRER, MAX (E S) student, Armour Institute of Technology, *Chicago*, (mail) 3227 Fullerton Avenue.

GARY, C. E. (M) draftsman, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*, (mail) 630 West Newell Street.

GRUNDMANN, WILLIAM R. (A) service manager, Mercer Motors Co., *Trenton, N. J.*

HABERKOST, NOEL F. C. (E S) student, Ohio State University, Columbus, Ohio, (mail) *Munroe Falls, Ohio.*

HEMEON, J. RUSSELL (J) student, Massachusetts Institute of Technology, Cambridge, Mass., (mail) 9 Standish Street, *Boston*, 24.

KELLER, K. T. (M) manufacturing manager, Chevrolet Motor Co., *Detroit*, (mail) 1177 Edison Avenue.

KURTI, A. (M) *Doylestown, Ohio.*

LEWENTHAL, ALLEN (A) service manager, Smith Motor Sales Co., *Phoenix, Ariz.*, (mail) 146 North 11th Avenue.

MARQUIS, ALBERT C. (A) salesman, Dayton Iron & Steel Co., *Dayton, Ohio*, (mail) P. O. Box 7.

MARTY, WILFRED H. (A) assistant chief inspector, Wright Aeronautical Corporation, *Paterson, N. J.*, (mail) 454 East 31st Street.

MEDDAUGH, RAY C. (J) Sutter & Meddaugh, *Columbus, Ind.*

MOOSBRUGGER, JOSEPH (J) airplane structural designer, Dayton Wright Airplane Co., *Dayton, Ohio*, (mail) 1005 North Broadway.

OSBORN, GEORGE W. (A) superintendent, bearing department, Hoyt Metal Co., *Granite City, Ill.*, (mail) 2132 G. Street.

PERRY, JAMES W. (A) general manager, automotive equipment and electrical departments, Johns-Manville, Inc., 296 Madison Avenue, *New York City.*

SHERRARD, JOE O. (E S) student, Ohio State University, *Columbus, Ohio*, (mail) 4 East Norwich Avenue.

SKELTON, O. R. (M) vice-president, Zeder-Skelton-Breer Engineering Co., *Newark, N. J.*, (mail) Robert Treat Hotel.

SKRIBA, LOUIS S. (E S) student, Armour Institute of Technology, *Chicago*, (mail) 725 West 17th Street.

SPRINGER, RUSSELL S. (M) vice-president and factory manager, Holt Mfg. Co., *Stockton, Cal.*

TUTHILL, LEON H. (A) shop superintendent, Reo Motor Car Co., New York City, (mail) 552 East 34th Street, *Brooklyn, N. Y.*

VERPLANK, A. J. (E S) student, Armour Institute of Technology, Chicago, (mail) 100 West Ridge Road, *Gary, Ind.*

WALWORTH, RICHARD H. (E S) student, Armour Institute of Technology, Chicago, (mail) 41 Broad Street, *Hillsdale, Mich.*

WHITE, ROBERT B. (J) lubrication engineer, Taxman Refining Co., Chicago, (mail) 116 South Michigan Avenue.